U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF ENTOMOLOGY—BULLETIN No. 50.

L. O. HOWARD, Entomologist.

THE COTTON BOLLWORM.

PREPARED UNDER THE DIRECTION OF THE ENTOMOLOGIST BY

A. L. QUAINTANCE AND C. T. BRUES.

WASHINGTON:
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1905.

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PLATE I.

ALASKA
DOMINION OF CANADA
HUDSON BAY
GREENLAND
ICELAND
UNITED STATES
MEXICO
NORTH PACIFIC OCEAN
HAWAIIAN IS.
NORTH ATLANTIC OCEAN
TROPIC OF CANCER
CANARY IS.
CAPE VERDE IS.
HAITI
PORTO RICO
JAMAICA
BARBADOS
GUATEMALA
S. SALVADOR
NICARAGUA
COSTA RICA
VENEZUELA
COLOMBIA
GUIANA
ECUADOR
EQUATOR
PERU
BRAZIL
BOLIVIA
PARAGUAY
URUGUAY
ARGENTINA
CHILE
SOUTH PACIFIC OCEAN
SOUTH ATLANTIC OCEAN
TROPIC OF CAPRICORN
GRAHAM LAND
BRITISH ISLES
DENMARK
NORWAY
SWEDEN
RUSSIA
RUSSIAN EMPIRE
GERMANY
FRANCE
AUSTRIA
RUMANIA
SPAIN
PORTUGAL
SICILY
TURKEY
MOROCCO
ALGERIA
TRIPOLI
FEZZAN
EGYPT
TIRIS
SAHARA DESERT
SENEGAL
FRENCH SOUDAN
SERRA LEONE
LIBERIA
ASHANTI
NIGER TER.
KAMERUN
ABYSSINIA
ITALIAN NORTHEASTERN AFRICA
BRITISH EAST AFRICA
KONGO FREE STATE
GERMAN EAST AFRICA
PORTUGESE WEST AFRICA
BR. CENTRAL AFRICA
PORTUGUESE EAST AFRICA
BR. SOUTH AFRICA
SOUTH WEST AFRICA
SOUTH AFRICAN REPUBLIC
ORANGE FREE STATE
NATAL
CAPE COLONY
MADAGASCAR
ARABIA
ARABIAN SEA
PERSIA
AFGHANISTAN
CHINESE EMPIRE
NEPAL
BHOTAN
BRITISH INDIA
BAY OF BENGAL
CEYLON
SIAM
COCHIN CHINA
HAINAN
FORMOSA
KOREA
JAPAN ISLANDS
PHILIPPINE IS.
MALAY PEN.
SUMATRA
BORNEO
CELEBES
JAVA
PAPUA OR NEW GUINEA
INDIAN OCEAN
AUSTRALIA
TASMANIA
NEW ZEALAND
GILBERT IS.
SAMOA IS.
NORTH PACIFIC OCEAN

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LETTER OF TRANSMITTAL.

United States Department of Agriculture,
Bureau of Entomology,
Washington, D. C., February 6, 1905.

Sir: I have the honor to transmit herewith for publication a full account of the bollworm, prepared under my direction by Messrs. A. L. Quaintance and C. T. Brues, special field agents of this Bureau. Mr. Quaintance has been engaged for two years in investigating the work of this very important and injurious insect, his work having been done mostly in the State of Texas. Mr. Brues assisted him for the larger part of the year 1904. The report is a very careful and complete account of the bollworm, which, although it has previously been written about by many entomologists, has never before received such a full consideration, and I recommend its publication as Bulletin No. 50 of this Bureau. The illustrations submitted are an essential part of the report.

Respectfully,

L. O. Howard,
Entomologist.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

Until the advent of the Mexican cotton boll weevil the bollworm was easily the most serious of the numerous insect pests of the cotton plant. The coming of the weevil has in no way lessened the destructiveness of the bollworm, though its injuries have been overshadowed by the more serious depredations of the former species.

The extent of bollworm ravages in recent years, notably in portions of Texas, was the occasion of an investigation supplementary to those previously made by the Bureau of Entomology. Under the provision of Congress for investigations concerning the cotton boll weevil, the senior author was detailed to the bollworm work in Texas in March, 1903. Headquarters were established at Victoria, where office and laboratory facilities were available in the building occupied by the force engaged in boll weevil investigations.

During that year special attention was given to field work, though such laboratory investigations as were possible were conducted. The principal results of field work in 1903 have been reported in Farmers' Bulletin No. 191 of this Department.

By reason of an increased appropriation the bollworm investigation was considerably enlarged in 1904. Headquarters were established at Paris, Tex., and a field laboratory was fitted up with necessary apparatus for thorough life-history studies. Field experiments were also greatly extended, the area under experiment amounting to about 600 acres. Three additional entomologists were employed in the work, and a fifth was engaged from July 1 to October 31. In addition to the authors, these were Messrs. F. C. Bishopp, A. A. Girault, and C. R. Jones. The senior author, under the direction of the Entomologist, has been directly in charge of the investigation in the laboratory and field. Laboratory details were supervised by the junior author, assisted by Mr. Girault. Messrs. Bishopp and Jones were occupied in making field observations and with work connected with the several experimental farms. Original observations by these gentlemen are credited to them in the pages of this bulletin.

Thanks are due many citizens of Texas and of other States, both planters and business men, for courtesies extended during the course

of the investigation. The several gentlemen on whose plantations the Department's experimental farms have been located have greatly facilitated the work by careful attention to instructions given as to the growing of the crop.

The principal results of field experiments in 1904 have been published in Farmers' Bulletin No. 212 of this Department. The present work deals more especially with results of laboratory investigations and other points of interest concerning the insect as a pest to cotton and other crops throughout its extended range.

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THE COTTON BOLLWORM.

(*Heliothis obsoleta* Fabricius.)

CLASSIFICATION AND SYNONOMY.

The adult of the bollworm is a moth belonging to the family Noctuidæ, division Trifidæ. Sir G. F. Hampson, in his Catalogue of Lepidoptera Phalænæ in the British Museum (1903), places the species in the subfamily Agrotinæ. Doctor Dyar, however, in his List of North American Lepidoptera,[a] follows Dr. J. B. Smith in assigning this species to the subfamily Noctuinæ.

The genus Heliothis was founded by Ochsenheimer in 1810 in his Schmetterlinge von Europa, while the species had been described in 1793 by Fabricius in his Entomologia Systematica under the name *Bombyx obsoleta*. Hübner in 1796 designated the insect in his Sammlung Europäischer Schmetterlinge as *Noctua armigera*. Owing to its great variation in color and markings, *Heliothis obsoleta* has at various subsequent times been described as new, and it has therefore a somewhat extended synonomy, as follows:

Bombyx obsoleta Fab., Ent. Syst., 3, I, p. 456, 1793.
Noctua armigera Hübn., Samm. Eur. Schmett., p. 370, 1796.
Phalæna zea Boddie, Am. Cotton Planter, July (?) 1850.
Heliothis pulverosa Walk., Brit. Mus. Cat., XI, p. 688, 1857.
Heliothis conferta Walk., Brit. Mus. Cat., XI, p. 690, 1857.
Thalpophila rubrescens Walk., Brit. Mus. Cat., XV, p. 1681, 1858.
Heliothis uniformis Wllgrn., Wien. Ent. Monatsschr., IV, p. 171, 1860.
Heliothis punctigera Wllgrn., Wien. Ent. Monatsschr., IV, p. 171, 1860.
Heliothis umbrosus Grote, Proc. Ent. Soc. Phila., I, p. 219, 1863.
Heliothis succinea Moore, Proc. Zool. Soc. London, p. 443, 1881.
Heliothis interjacens Grote, Bul. Brooklyn Ent. Soc., III, p. 30, 1882.

The original description of *Bombyx obsoleta* by Fabricius[b] is as follows:

B. alis deflexis flavescentibus: macula media strigaque postica obsoleta obscurioribus. Habitat in Americæ meridionalis Insulis Dom. Smidt.

[a] Bul. 52, U. S. National Museum, p. 185, 1902.

[b] Ent. Syst., 3, I, p. 456, 1793.

Media. Antennæ simplices. Corpus flavescens. Alæ flavescentes macula media, obscuriore, postice striga obsoleta punctis minutissimis fuscis notata. Margo posticus fuscescens. Posticæ flavescentes margine postico, fusco.[a]

VARIETIES.

Two varieties and a subvariety of the bollworm moth have been designated from the United States; one variety from Hawaii, one from Europe, and one from Australia, with two subvarieties. With the forms occurring in the United States, at least, there is almost every intergradation in color and markings, and it is doubtful if these may be referred to in a more definite way than as the more abundant types. In a collection of 65 moths, bred during the present investigation from larvæ taken on corn, cotton, and other plants in Texas, 35 may be classed as variety *ochracea*, with some of them approaching *fusca*, and 30 as variety *umbrosa*. The forms which have thus far been indicated are given in the table below, with their essential points of difference, as taken from the British Museum Catalogue (l. c.), and Tutt's British Noctuæ and Their Varieties.[b]

HELIOTHIS OBSOLETA Fab.

Table of varieties and subvarieties.

(1) *ochracea* Ckll. Ordinary tawny colored form figured in Fourth Rept. U. S. Ent. Comm., 1885, pl. 3, fig. 7.

(2) *fusca* Ckll. Dark brown (European).

(3) *umbrosa* Grote. Usually rather large, paler, and more olivaceous than the European type (Southern United States especially), the larva, the common bollworm.

  (*a*) sub-var. *eumaculata* Ckll. Stigmata margined with ferruginous (Colorado).

(4) *hawaiiensis*, n. var. Fore-wing with prominent angled dark brown median band, diffused on outer side (Hawaii).

(5) *rubescens*, hind-wings with the ground color orange yellow (Australia).

  (*a*) Head, thorax, and fore-wing suffused with rufous.

  (*b*) Head, thorax, and fore-wing suffused with dark pink.

COMMON NAMES.

Owing to the fact that the bollworm attacks a great variety of plants, and to the further fact that it occurs in most parts of the civilized world, it has become known under numerous common names.

In the United States it is very generally known under the name of bollworm or corn-ear worm. In the States of the cotton belt the former name is very generally used in referring to this species, or it is

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[a] A bombyx, with wings deflexed and yellowish; with a middle spot and posterior obsolete streak, rather obscure. Habitat, islands of South America [West Indies?]. Collector, Father Smith. Of medium size. The antennæ simple. The body yellowish, with wings yellowish, with a more obscure middle spot. Posteriorly with an obsolete streak which is spotted with very small punctures. Hind margins brownish. Hind wings yellowish, with posterior margin fuscous [smoky?].—E. A. S.

[b] British Noctuæ and Their Varieties, III, p. 128, 1892.

simply designated the "worm," in distinction to the so-called "caterpillar" or "army worm," the larva of *Alabama* (*Aletia*) *argillacea* Hbn. In certain portions of the cotton belt, as southern Louisiana and Mississippi, the insect is commonly called the "sharpshooter" or "sharpshooter-fly." It should be stated in this connection that the name sharpshooter is properly applicable only to certain homopterous insects of the genus Homalodisca, especially *Homalodisca triquetra* Fab., a very different insect from the cotton bollworm.

The almost universal injuries of the insect to corn have resulted in the use of three names for the bollworm, descriptive of the parts attacked. Thus, in the spring, when infesting the "buds" of young field corn, it is known as the bud worm, and later, when the unfolding tassels are attacked, it is called the tassel worm. But the larva is most frequently met with infesting roasting ears and has thus become well known under the name of corn-ear worm. It has been designated in Minnesota by Lugger as the sweet-corn moth.

On tomatoes the frequent considerable injury by the larvæ to the green and ripening fruit has given rise to the name of tomato fruit-worm, or simply tomato worm. In southern New Jersey, according to Dr. J. B. Smith, the larvæ are known to tomato growers as heart worms.

Tobacco growers know the bollworm under the name of bud worm, though two species of Heliothis are concerned in injury to the tender buds of the tobacco plant.

In New South Wales our bollworm is known as the maize moth; in Cape Colony, South Africa, as the peach under-wing, from its depredations on this fruit, and also as "risper," signifying caterpillar.

Throughout this bulletin the name "bollworm" is adopted, as its present consideration refers more especially to its depredations on cotton.

GEOGRAPHICAL DISTRIBUTION.

But few, if any, species of insects are more widely distributed throughout the world than is our cotton bollworm. Within the parallels of about 50° north and south latitude, the localities of its occurrence form an almost complete girdle around the world. The most southerly recorded point of its occurrence is Dunedin, New Zealand (South Island), south latitude about 46°, and the most northerly is Sjælland, Denmark, north latitude about 55° 30′. In its vertical distribution it is known to occur at sea level at many places, and it is recorded from Milpas, Durango, Mexico, by Druce at an altitude of 5,900 feet. In Natal, according to Mr. Claude Fuller (in lit.), it has been noted from sea level to 5,000 feet above.

In the accompanying outline map of the world (Pl. I) the principal points of its occurrence are indicated by dots. In the United States

it occurs practically throughout. The map is based on information gathered from different sources, but principally from the British Museum Catalogue of Lepidoptera (l. c.), and from letters from foreign entomologists to Dr. L. O. Howard.

The following classified list will indicate more exactly the localities, States, provinces, etc., where the species is known to occur. It is very probable that it occurs in greater or less abundance throughout the various countries from which it is recorded, and it may perhaps now be said that the prophecy of Grote, made some years ago, "We shall soon write after its habitat, 'The World,'" has been practically fulfilled:

Canada: Ontario (Ottawa); Toronto; Manitoba (Beulah).

United States: Throughout, except possibly in Montana and Washington.

Mexico: Morelos (Cuernavaca); Jalapa; Durango (Milpas); St. Maria; Mexico City.

Central America: Guatemala (San Geronimo, Topote); Costa Rica.

Panama: Volcan de Chiriqui.

South America: Venezuela; Rio Grande do Sul (Porto Alegre); Brazil (Rio); Peru (Callao); Chile (Coquimbo).

West Indies: Jamaica; Barbados; St. Vincent; Porto Rico (San Juan, Mayaguez); Cuba (Habana); Dominica.

Europe: Britain; France (Nice); Germany; Spain (Gibraltar); Russia (Sarepta); Sicily; Italy (Piedmont, Lombardy, central and southern Italy); Denmark: Zealand (Sjælland); Austria-Hungary: Budapest (vicinity); Transylvania (Háromszék).

Africa: Madeira Islands; Canary Islands; Kongo; Soudan (Geht el Meghahid); Abyssinia; British East Africa (Machako, Tana River); North Gamiland; Madagascar; Transvaal; Natal (Malvern, Durban); Basutoland (Masite); Cape Colony (Knysna, Grahamtown, Cape Town). According to Lounsbury (in lit.), this species is well spread over Cape Colony, Orange River Colony, and Transvaal.

Asiatic Turkey: Arabia (Aden); Syria (Lebanon).

India: Kashmir (Govrais Valley, Kuijar); Northwest Himalayas; Simla; Dalhousie; Akhor; Campbellpar; Dharmsala; Deyra Dun; Allahabad; Sikhim; Sird; Kutch (Kutchur?); Bombay; Mhow; Madras; Ceylon; Nilgiris (Nilgiri?); Azimgarh; Chengalpot; Tanjore; Cawnpore; Bengal; Patna.

China: Shanghai; Chusan; Chang-yang; Washan.

Japan: Yokohama; Fushiki; Formosa.

Straits Settlements: Perak (Kinta Valley); Singapore.

East Indies: Java.

Southern Pacific: Gilbert Islands; Navigator Islands.

Australia: North Australia (Point Darwin, Condillas); West Australia (Sherlock River, Freemantle, and, according to Lea, from Albany to Champion Bay and to some distance inland); Queensland (Brisbane); New South Wales (Moreton Bay, Sydney); Victoria (Gisborne); Tasmania (Launceston); New Zealand (Dunedin, Auckland); South Australia (Adelaide, and generally throughout this State).

ORIGINAL HOME.

In the case of insects so widely distributed it is of interest to determine, if possible, that part of the world to which they are indigenous and from which they have spread to other countries. Many of our most injurious species have been introduced from foreign countries,

being here much greater pests than in their native homes. This result is due in part, at least, to the fact that their native parasitic and predaceous enemies have not been introduced along with them, and they are thus able to develop largely unmolested by these important checks. The proposition, therefore, has been to determine the original home of an injurious introduced species, and then to obtain its enemies and to array them against it in hope of thereby securing its control.

Regarding the insect under discussion—the cotton bollworm—there are but few data with a possible bearing on its native home, and these are largely of a contradictory nature. That it is really indigenous over its present extended range is scarcely to be admitted. While there are numerous truly cosmopolitan families and a large, though proportionately less, number of genera, the truly cosmopolitan species of animals are comparatively few. In the case of many widely distributed insects the possible accidental influence of man in furthering their distribution really makes it doubtful whether they are indigenous throughout their known range. *Anosia plexippus* Linn. and *Vanessa* (*Pyrameis*) *cardui* Linn., among butterflies, appear to enjoy an almost world-wide distribution, but the ease with which pupæ of these could be transported and, further, the vigorous flight of the butterflies themselves when once established would enable them to soon become quite common over an entire continent.

Reference to Plate I will show how widely the bollworm is at present known to be distributed over the world. Rejecting the idea of its being truly indigenous over this vast territory, it may be worth while to consider some facts bearing on the subject of its original home.

As has been noted in the original description of this species by Fabricius under the name *Bombyx obsoleta*, its habitat is given as Americæ Meridionalis Insulis. Accepting the identity of *Bombyx obsoleta* with our bollworm moth, as held by Sir G. F. Hampson and others, the species was first described from a specimen or specimens probably from the West Indies. Apparently the earliest reference to the bollworm as depredating on crops comes from the United States. By 1820 its ravages on cotton were the occasion of a short note in the American Farmer by a correspondent writing under date of September 20, 1820, to the effect that the pods of his cotton had been attacked by a large green worm from 1 to 1½ inches long, which ate its way into the pod and did not leave it until it had completed the destruction. Some of the worms were smaller; some were brown and red. The injury seemed to be severe, with the prospect of one-fourth of the crop being destroyed.

By 1841 the bollworm had become prominent as an enemy to cotton and corn in the Southern United States, and it is recorded as attacking corn in Illinois in 1842.

As early as 1853 its distribution, according to Guenée,[a] was "Central Europe, North America, South America, East Indies, New Holland, and probably in other countries of the globe."

At the March meeting of the London Entomological Society in 1869 specimens of the bollworm moth were exhibited by a Mr. Bond from the Isle of Wight, Java, and Australia.

Mr. Grote, a well-known student of the Noctuidæ, to which family our insect belongs, has expressed the opinion that it is native to America, especially because it feeds here on some peculiarly American genera of plants. Its rare occurrence in Europe as compared with its abundance and destructiveness in America is also cited, and from its occurrence in Australia and Java the query is raised: Has it not reached Europe from America by a westward route? As bearing on this point it is to be noted, as has previously been mentioned, that usually species introduced into a new country become much greater pests than in their original home, and on this basis the bollworm should be added to our already long list of imported pests.

Mr. J. G. O. Tepper, of the Public Museum of South Australia (in lit.), says:

> The species [*Heliothis obsoleta*] appears to be indigenous throughout the continent [Australia]; a specimen was brought by the Elder exploring expedition in 1892 from a till then uninhabited region in Central Australia, and of the pale variety.

Mr. E. E. Green, the well-known student of scale insects, says:

> The very fact of extensive damage by any insect may of itself almost be accepted as proof of its foreign origin. Looking over the list of the different scale insects occurring in Ceylon, I find that all of the more troublesome species have been previously described from some other country and are, therefore, presumably imported insects.

In America, however, we have numerous native insect species that are first class pests, as the Colorado potato beetle, the plum curculio, and others, so that the argument as applied to our conditions loses much of its force.

More data of this character could be presented, but would serve no useful purpose in clearing up the question of the native home of the bollworm. Hardly anything can be inferred from a consideration of the food plants of the insect, for it is practically omnivorous. Its preferred food plant in the United States is corn, and probably also throughout its range in other countries where this crop is grown. Its second choice in this country is cotton, a plant which has for centuries been grown in many parts of the world. Its third choice is probably tomatoes, a plant held to be native to Peru.

Except in the United States but little has been recorded concerning its parasites, and these are all native to America.

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[a] Lep. Noc., II, p. 181.

FOOD PLANTS.

Throughout its range a great variety of plants belonging to many different natural orders are known to furnish subsistence to the bollworm. On some of these, as various weeds, its occurrence is more or less accidental, due to the indiscriminate habits of the moth in egg laying, the food being plainly not suitable for the best growth and development of the larva. In the case of many vegetables and ornamental and fruit plants, however, these are fed upon with evident relish, and the larvæ are able to develop normally. Reports of occasional severe injury to plants of this character may be held to indicate the capabilities of the species, under favorable conditions, for depredations in the future. With a species of such general feeding habits severe local injury, in the absence of its preferred food plants, might reasonably be expected to occur to some of the numerous other crops which it is known to attack.

Many of the plants mentioned in the subjoined table are, in foreign countries, seriously ravaged by this pest. Important injury in the United States is confined principally to cotton, corn, tomatoes, and tobacco, concerning which a more detailed account will be given on another page.

TABLE I.—*Food plants of Heliothis obsoleta.*

Food plants.	Parts injured.	Reported from.
Convolvulaceæ:		
Morning glory (*Ipomœa commutata*).	Green fruit	United States.
Bind weed (*Ipomœa* sp.)	Foliage	Do.
Chenopodiaceæ:		
Pigweed (*Chenopodium* sp.)	Stems, foliage	Do.
Amarantaceæ:		
Amaranth (*Amarantus* spp.)	Green seeds	Do.
Labiatæ:		
Stachys agraria	do	United States (south Texas).
Cucurbitaceæ:		
Squash (*Cucurbita pepo*, var. *condensa*).	Vines, flowers, young fruit	United States.
Pumpkin (*Cucurbita pepo*)		Do.
Cucumber (*Cucumis sativa*)	Vines, fruit	Do.
Muskmelon (*Cucumis melo*)	Young fruit	Do.
Watermelon (*Citrullis vulgaris*)	do	Do.
Compositæ:		
Cocklebur (*Xanthium strumarium*).	Foliage, stems	Do.
Sunflower (*Helianthus* sp.)	Flower-heads	United States, India.
Erigeron canadense	do	United States.
Dahlia (*Dahlia* sp.)	(?)	Cape Colony.
Cannaceæ:		
Canna (*Canna indica*)	Tender central bud; seed capsules.	United States.
Malvaceæ:		
Cotton (*Gossypium* spp.)	Squares, bolls, flowers, stems, foliage.	Southern United States, India (?).
Okra (*Hibiscus esculentus*)	Green seed-pods, stems	United States.
Malva borealis	Green seed-pods	Do.
Sida spp	do	Do.
Hibiscus sp		Cape Colony.
Graminæ:		
Indian corn (*Zea mays*)	Tender "bud," tassel, ears	United States, Porto Rico. Brazil, Australia, Europe, Cape Colony.
Sorghum ([illegible]*hum vulgaris*, var. *sacchar*[illegible]	Tender central "bud," green seeds.	United States, Natal.

TABLE I.—*Food plants of Heliothis obsoleta*—Continued.

Food plants.	Parts injured.	Reported from.
Gramineæ—Continued.		
Millet (*Chætochloa italica*)	Green seeds	United States.
Crab grass (*Panicum sanguinale*)	Foliage	Do.
Colorado grass (*Panicum texanum*)	do	United States (Texas).
Sugar cane (?) (*Saccharum officinale*).	Tender central "bud"?	Southern United States.
Wheat (*Triticum* sp.)	Young plants	Australia.
Oats (*Avena sativa*)	do	Do.
Barley (*Hordeum* spp.)	do	Do.
Kafir corn	(?)	Cape Colony, Natal.
Rice (*Oryza sativa*)	(?)	India.
Solanaceæ:		
Tomato (*Lycopersicum esculentum*).	Green and ripening fruit, stems, foliage.	United States, Europe, Cape Colony, Natal.
Jimson (*Datura stramonium*)	Green seed capsules	United States.
Ground cherry (*Physalis* spp.)	Green and ripening berries	Do.
Cape gooseberry (*Physalis peruviana*).	(?)	Ceylon, India.
Pepper (*Capsicum annuum*)	Pods	United States.
Tobacco (*Nicotiana tabacum*)	Foliage, tender "buds," green seed-capsules.	United States, Japan, Australia, Italy.
Nicotiana repanda	do	United States (Texas).
Egg plant (*Solanum melongena*)	Green and ripe fruit	United States.
Solanum spp	Green berries	Do.
Potato (*Solanum tuberosum*)	(?)	India.
Vitaceæ:		
Grape (*Vitis* var. ?)	Foliage	United States (California).
Urticaceæ:		
Fig (*Ficus carica*)	(?)	United States.
Hemp (*Cannabis sativa*)	(?)	United States (?), Europe, India.
Iridiaceæ:		
Gladiolus (*Gladiolus* var. ?)	Stems, flower buds	United States.
Geraniaceæ:		
Geranium (*Geranium* var. ?)	(?)	Do.
Pelargonium (*Pelargonium* sp. ?)	(?)	Australia.
Cruciferæ:		
Cabbage (*Brassica oleracea*)	Foliage	United States, Cape Colony.
Collards (*Brassica oleracea*)	Stems	United States.
Liliaceæ:		
Asparagus (*Asparagus officinale*)	Berries (?)	Do.
Rosaceæ:		
Peach (*Prunus persica*)	Green and ripening fruit, flower buds.	United States, Cape Town, South Africa.
Plum (*Prunus* sp. ?)	Green fruit, flower buds	Cape Town.
Prune (*Prunus* sp. ?)	do	Do.
Pear (*Pyrus communis*)	Foliage	United States (California).
Strawberry (*Fragaria chiloensis*)	"Crown"	United States.
Rose (*Rosa* spp.)	Flower buds	United States, Ceylon.
Papaveraceæ:		
Opium poppy (*Papaver somniferum*)	Seed capsules	India.
Leguminosæ:		
Alfalfa; Lucern (*Medicago sativa*)	Foliage, tender stems	United States, Europe, Cape Colony.
Chick-pea, gram (*Cicer arietinum*).	Foliage, pods	Europe, India.
Acacia sp	(?)	Cape Colony.
Beans, Lima and string (*Phaseolus vulgaris*).	Pods	United States, Cape Colony.
Peas (*Pisum sativum*)	do	Do.
Sweet peas (*Lathyrus odoratus*)	Pods (?)	Cape Colony.
"Khesari" (*Lathyrus sativus*)	Pods (?)	India.
Pulse (*Dolichos lablab*)	Pods (?)	Do.
Cowpea (*Vigna catjang*)	Pods	United States.
Erythrina herbacea	do	Do.
Milk vetch (*Astragalus caryocarpus*)	do	Do.
Resedaceæ:		
Mignonette (*Reseda* sp.)		Europe.
Caryophyllaceæ:		
Carnation (*Dianthus caryophyllus*).		Cape Colony.

In the laboratory at Paris bollworms were fed on the following plants, which were eaten with évident relish:

Corn.	Gourd.	Rose.	Bindweed.
Cotton.	Cucumber.	*Amarantus* spp.	*Stachys agraria.*
Tomato.	Nasturtium.	Tobacco.	*Physalis angulata.*
Apple.	Castor bean.	Catalpa.	*Solidago* sp.
Peach.	Millet.	Blackberries.	*Canna indica.*
Irish potato.	Alfalfa.	Bermuda grass.	*Datura stramonium.*
Sweet potato.	*Taraxacum vulgare.*	*Rudbeckia* sp.	*Chenopodium* sp.
Cowpeas.	*Helianthus tuberosum.*	Poke weed.	*Sida* sp.
Garden peas.	Green peppers.	*Solanum* spp.	
Squash.	Okra.	*Erigeron* spp.	

The food plants of the bollworm, as at present known, are thus seen to number 70, distributed in 21 natural orders. If to these be added the plants on which the larvæ have been fed in confinement, the list becomes somewhat increased.

STATUS OF BOLLWORM IN FOREIGN COUNTRIES.

Throughout its extended range the bollworm is nowhere so well known as in the southern United States in connection with its injuries to the cotton crop. Its injuries in foreign countries are, however, in some sections not inconsiderable, and attention may appropriately be called to its status as a pest in other countries than our own.

Throughout the countries of Europe its injuries are, on the whole, comparatively insignificant. In Great Britain and Ireland, according to Mr. E. A. Shipley (in lit.), well-authenticated British specimens of the moth are so rare as to sell at from $2.50 to $4 each.

Dr. Paul Marchal writes that bollworms were observed by him injuring tomatoes in middle France in 1900 and 1901, and also injuring corn in north Spain. In Hungary, according to Dr. Josef Jablonowski, moths are very rare and larvæ are unknown. A related species, *Heliothis dipsaceus* Linn., is at times troublesome, feeding on corn, flax, peas, potatoes, and other crops.

Dr. Antonio Berlese, of the Royal High School, Portici, Italy, advises (in lit.) that the bollworm in Italy attacks principally tobacco and Indian corn. Its injuries are not ordinarily important, and gathering the larvæ by hand and destroying them is the method followed in its control. Three generations annually are considered probable.

Concerning the status of the bollworm in Cape Colony, South Africa, Mr. Charles P. Lounsbury, Government entomologist, writes that it is one of the most common of the lepidopterous insects of the Cape, its larva being well known to farmers, fruit growers, and gardeners alike. In feeding habits the larva is almost omnivorous, attacking pear, prune, plum, peach, lucern (alfalfa), cabbage, tomatoes, corn,

various flowers, and pine. Often serious injury is done to early tomatoes and peas, and much complaint is made of injury to buds of flowers and young fruit of peaches, plums, prunes, etc., of which 50 or more per cent are quite often scarred. Corn is generally infested. Hand picking is largely practiced to protect orchard trees, and thorough cleaning up for protecting vineyards.

In Natal the pest is apparently less destructive. Mr. Claude Fuller, formerly Government entomologist, has noted its injuries to corn, Kafir corn, and tomatoes, but generally the damage is slight.

In Australia the insect is very generally distributed over the central parts, according to Mr. J. G. O. Tepper, of Adelaide, it being one of the most common of the larger moths. The larvæ feed almost indiscriminately, attacking wheat, barley, and oats while these crops are young, and most other herbaceous plants in all stages, the former crops being attacked at or near the ground, much after the manner of cutworms. Native crows and magpies feed on the larvæ, rendering much service in this way. It is noted that native grasses are not attacked. Several generations annually probably occur.

Mr. Arthur M. Lea, writing concerning this same insect in Australia, mentions an instance where the larvæ, leaving the flowers of "everlasting," on which they were feeding, appeared to migrate simultaneously in true army-worm fashion, attacking a near-by paddock of oats, which was completely destroyed. The same gentleman states that the bollworm is very rare in Tasmania, only two specimens having been obtained during a period of four years.

In Ceylon, Mr. E. Ernest Green, of the Royal Botanic Gardens, writes that the bollworm does not there rank as a serious pest. The larvæ are principally injurious to flowers, as rose buds, and to vegetables, as the fruit of *Physalis peruviana*, the Cape gooseberry. Hand picking is the only method employed in its control.

In Japan, according to Mr. Yasuchi Nawa, of Gifu, the bollworm is most injurious to tobacco, cotton not being especially injured. Other plants attacked are flax, corn, cucurbits, and hemp (*Cannabis sativa*). The insect is controlled by destroying the eggs by the use of kerosene emulsion. Three or four generations occur annually.

Attention should here be called to the occurrence in the cotton fields of Egypt of an insect there known as the bollworm, which is, however, a species quite different from the bollworm of the United States. The Egyptian bollworm resembles our own mostly in its habit of feeding on cotton bolls. Its life history presents numerous points of difference. Mr. George P. Foaden, in the Journal of the Khedival Agricultural Society for May and June of 1899, page 940, gives an account of this species under the name of *Earias insulana*.

ECONOMIC STATUS IN THE UNITED STATES.

As shown on page 17, the food plants of the bollworm in the United States comprise a very long list. It is best known, however, as a pest of corn, cotton, tomatoes, and tobacco, its injuries to the other mentioned food plants being as yet of comparatively little importance.

INJURY TO CORN.

Corn is without doubt the preferred food of the bollworm, and it is subject to attack from the time the plants are 12 to 18 inches high in the spring until late in the summer and fall, when the yellowing leaves and stalks and ripening ears are no longer attractive. Of the different types, sweet corn is most generally infested, which may be taken as evidence of its partiality for the sweet varieties. In the South generally, the culture of sweet corn for market or home use is usually very unsatisfactory by reason of the depredations of this insect; and it is not attempted so generally as farther north. Early-planted sweet corn is just coming into tassel and silk as moths from hibernating pupæ make their appearance. The plants are thus stocked with eggs, the leaves, stalk, tassel, ears, and silks often being literally covered with them, numbering, for a single plant, not infrequently from 300 to 500. The tender central roll of leaves, or "bud," the unfolding tassel, and the milky kernels of the ear are attacked by the larvæ, and the plant soon presents a sorry sight. Scarcely an uninfested ear may be found. The injury may be confined to the destruction of the terminal portion, or large irregular cavities may be eaten quite the length of the ear. This injury, together with the quantities of filthy excrement voided by the larvæ in their rapid growth, practically renders the product unfit for market purposes, though more or less injured ears are often found for sale. The citizens of the South are, therefore, largely deprived of this favorite vegetable on account of the presence of this pest.

The species has much the same character in the more northern States, but the severity of attack and the completeness of destruction are much less pronounced, except during occasional years. In New Jersey, Delaware, Maryland, Ohio, Indiana, Illinois, and bordering States, where the cultivation of sweet corn for market and for canning purposes has attained considerable proportions, the ravages of the insect one year with another bring about a considerable financial loss. Frequent mention is made in the literature of economic entomology of the depredations of the bollworm on sweet corn, the loss being variously estimated at from 10 to 50 per cent of the crop. Extreme cases have been recorded where the injury has been so severe that no attempt was made to even utilize the crop. Actual losses suffered by growers of sweet corn for commercial purposes may be only approximately indicated. Statistics are not at hand bearing on the

pronounced in 1903 than in 1904. This was due not only to the more favorable weather conditions for bollworms during late July and August, but to the general lateness of crops, due to an unusually wet spring, which everywhere delayed planting from three to five weeks.

The following estimates of bollworm injury to cotton in several counties of Texas during 1903 have been made from all obtainable data, including personal investigations, and will illustrate the possibilities of injury of this species under exceptionally favorable conditions:

TABLE II.—*Estimated bollworm injury in certain counties of Texas in 1903.*

County.	Percentage of crop destroyed.	County.	Percentage of crop destroyed.
Navarro	20 to 25	Lamar	40 to 50
Henderson	15 to 20	Delta	50 to 60
Limestone	20 to 25	Hunt	30 to 35
Falls	8 to 10	Hopkins	25 to 30
Bell	8 to 10	Kaufman	25 to 30
Robertson	15 to 20	Van Zandt	20 to 25
Fannin	50 to 60		

It should not be understood that injury was confined to these counties. The injury, in fact, was quite ge eral over the principal cotton-producing counties of the State. Likewise in Louisiana, Mississippi,

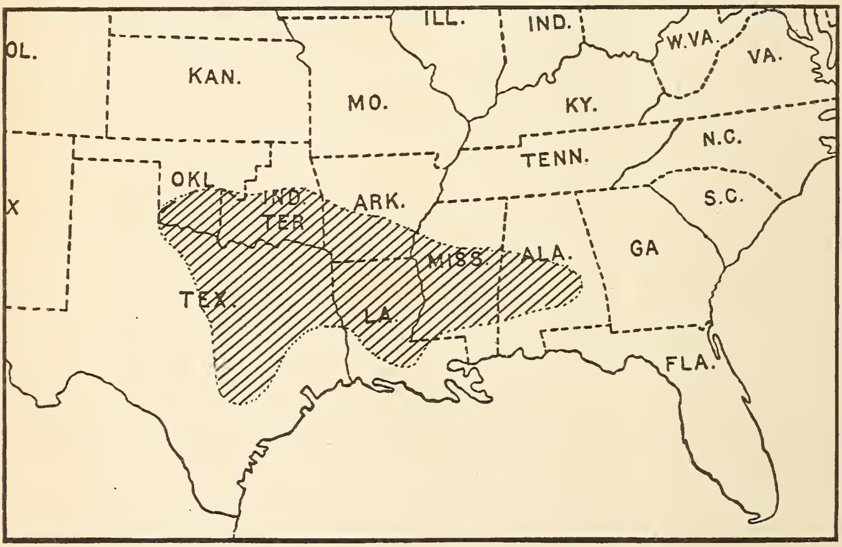
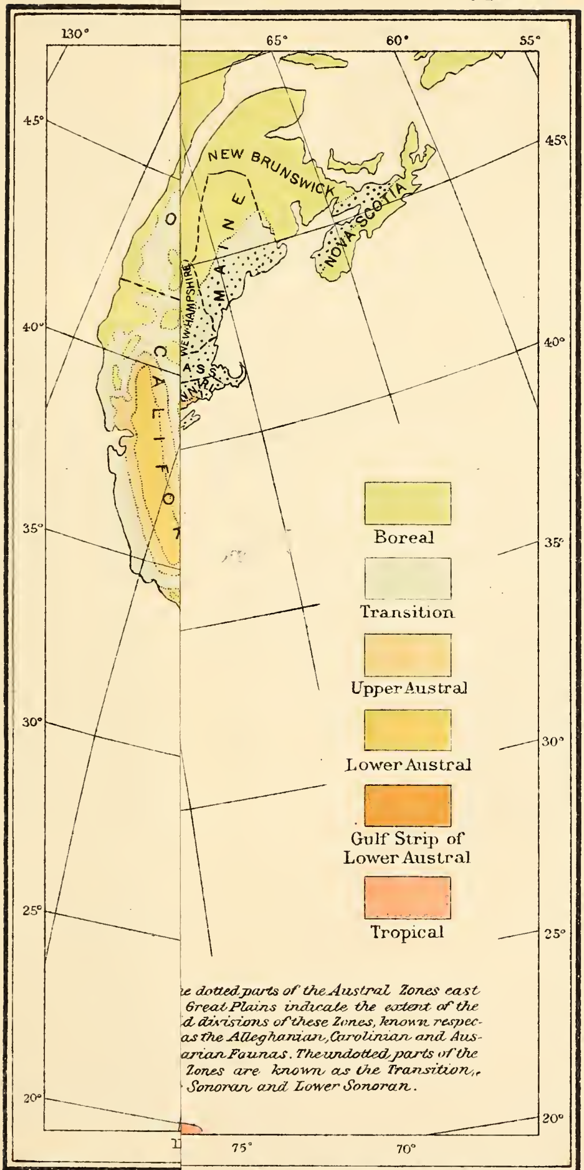


FIG. 1—Map of area infested by bollworm (from Quaintance and Bishopp).

Indian Territory, and Arkansas bollworm injury was very severe. The area most seriously injured in 1904 is shown by the shading in the accompanying illustration (fig. 1).

From evidence collected and from personal investigation it is believed that an average annual injury of 4 per cent to the cotton crops of the



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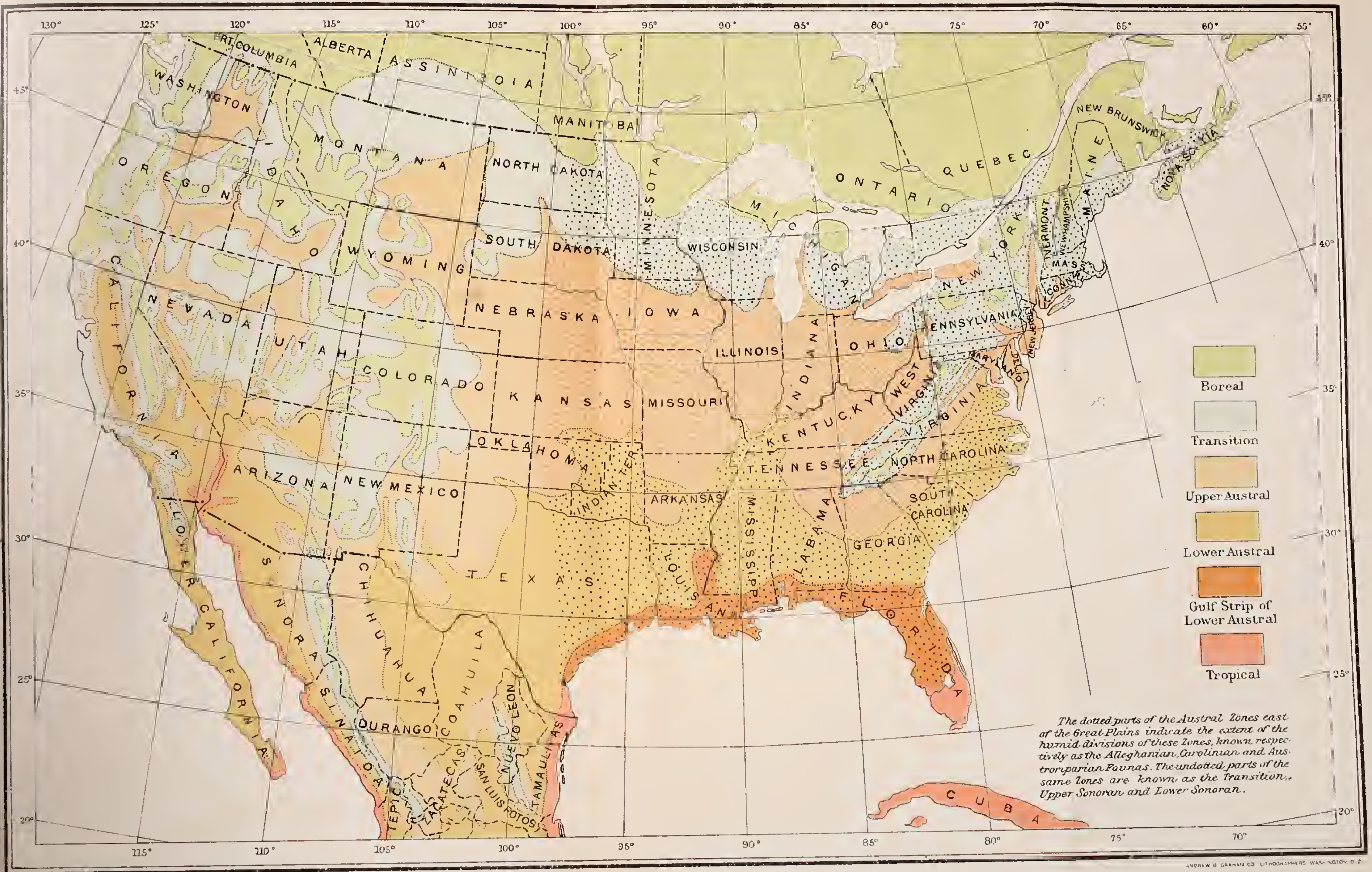

Corrected to December, 1897

LIFE ZONES OF THE UNITED STATES

BY

C. HART MERRIAM.

above-mentioned States would be a most conservative estimate. For the purposes of the present computation, bollworm injury in the States of Alabama, Georgia, Florida, the Carolinas, and the other cotton-growing States not mentioned may be ignored as of little importance.

The total value of cotton fiber and seed for the States of Texas, Louisiana, Mississippi, Indian Territory, Oklahoma, and Arkansas for 1899 is given by the Twelfth Census as $213,695,256. Four per cent of this amount is $8,547,810, the approximate annual tax of the bollworm on the cotton planters of these States.

INJURY TO TOMATOES.

Bollworm injury to tomatoes is variable and hard to more than approximately estimate. Injury by the first and second generations of larvæ is probably most severe, but reports of depredations in the late summer and fall are not wanting. The destruction of the early fruit augments the loss. In the commercial tomato-growing regions of the South, especially in Florida, Mississippi, and eastern Texas, complaints of severe injury are frequent; likewise in Maryland, New Jersey, Delaware, and other States, where large quantities of tomatoes are grown for canning purposes, the average annual injury is doubtless quite important. A possible basis for an estimate of loss to tomato growers by the bollworm is to be found in the statistics of the pack of this vegetable in the United States for 1900, which are given by the Twelfth Census as 5,495,093 cases of twenty-four 3-pound cans each. At the minimum valuation of $1.46 per case, the crop in 1900 was worth $8,022,835. Placing the average annual loss to this crop by the bollworm in the United States at 2 per cent, which is undoubtedly a very conservative estimate, the amount is $160,456.

Bringing together the losses to the afore-mentioned crops, there is shown a total of $27,129,119 as the yearly tax of this species on growers of corn, cotton, and tomatoes in the United States.

The extent of losses to various other crops, such as tobacco, alfalfa; cowpeas, various garden vegetables, and others, would increase this amount somewhat, and the sum total of losses from its depredations in this and foreign countries would be an amount sufficient to easily place the bollworm amongst the foremost injurious species of the world.

DISTRIBUTION AND DESTRUCTIVENESS IN RELATION TO LIFE ZONES.

With the probable exception of the Boreal, the cotton bollworm is known to occur in all of the life zones of North America, as mapped out by Doctor Merriam (Pl. II), namely, the Transition, Upper Austral, Lower Austral, and Tropical.

TRANSITION ZONE.

The species occurs well up in the Transition zone, if not indeed overlapping on the southern limits of the Boreal zone, though in this northern latitude it is apparently not very destructive. It is here recorded as injurious to late sweet corn and also tomatoes. Rather severe injury was reported in the vicinity of London, Ontario, in 1898, by Dr. James Fletcher,[a] and also by Mr. J. Dearness.[b] Several fields of corn were infested, varying in extent from about 20 to 95, or in one case nearly 100 per cent, with from one to several larvæ in each ear. In a letter concerning this species Doctor Fletcher states:

> *Heliothis armiger* [*obsoleta*] is sometimes abundant and destructive to late sweet corn, the larvæ at that time being of all sizes to full grown. * * * Moths are out at Toronto and here [Ottawa] by the end of September and sooner. * * * We have also received specimens from Beulah, Manitoba, but the species is decidedly not common.

Injury to sweet corn in 1892 is reported[c] from Farmington, Me., a town on the border line of the Boreal and Transition zones in that State. The identity and character of the insect seem to have been quite unknown to those suffering from its ravages, which may be taken as evidence of its infrequent occurrence. No records have been found to indicate its occurrence in the numerous patches of the Boreal zone along the Allegheny and the mountain chains of the West, although it is known to occur in numbers in adjacent areas of the Transition zone. It may, therefore, perhaps be safely inferred that the insect is not able to extend itself permanently into the Boreal zone, by reason of temperature and other conditions.

It is pertinent to mention that in New Mexico Prof. T. D. A. Cockerell, who has given considerable attention to the life zones of insects, records[d] the species only from the area designated by him Upper (including middle) Sonoran.

The restraining influence of low and sudden changes in temperature on the successful existence and increase of species of more southern occurrence, in their northward spread, has been recently commented upon[e] by Doctor Chittenden, of this Bureau. According to this gentleman's observations the bollworm was comparatively rare on corn and other crops, which it commonly infests in the vicinity of Washington during the season following the severe freezes of February and March, in 1899. The severe character of the winters of the more northern States, coupled with the relatively low sum of effective temperature, no doubt has an important bearing on the comparative immunity of this territory from serious injury.

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[a] Rept. Ent. Soc. Ont., 1898, p. 82.

[b] Ibid., p. 62.

[c] Ann. Rept. Maine Agric. Exp. Sta., Pt. IV, 1892, p. 119.

[d] Bul. 24, N. Mex. Agric. Exp. Sta., p. 35.

[e] Bul. 22, n. s., Div. Ent., U. S. Dept. Agric., p. 56.

In the more southern part of the Transition zone the insect is notably more successful, though nowhere in this zone is it a pest of regular occurrence or of any considerable importance. In Massachusetts it was reported as quite abundant in 1894, and its presence had been noted in sweet corn several years previously in certain of the smaller towns in the neighborhood of Boston. It would appear, however, that the bollworm becomes thus numerous at rather long intervals. According to Doctor Fernald (in lit.) only three examples were received by him at the Massachusetts Experiment Station from 1899 to 1904.

In Michigan, which is largely within the Boreal and Transition zones, the bollworm is also of comparatively rare occurrence in injurious numbers. Thus Mr. Tyler Townsend states[a] that the species came under his observation only once during a period of fourteen years, namely, in 1881, when the larvæ were frequently found in ears of green corn. In Minnesota, according to Doctor Lugger,[b] the insect does not winter, all individuals being killed in late fall, thus necessitating their reintroduction each year. In commenting upon this statement Doctor Fletcher remarks that it is his opinion that some of the insects, at least, hibernate in Canada as pupæ.

The almost total absence of references to this species in experiment station and other literature from the Dakotas, Montana, Wyoming, and Washington indicates its comparative scarcity, at least as a pest. In a recent letter Prof. Avon Nelson states it as his belief that the bollworm does not occur in Wyoming[c]; Professor Cooley does not know of its presence in Montana; while Prof. W. H. Lawrence advises that according to his information it does not occur in Washington. It is, however, reported from Idaho and Oregon. The absence of sufficient data will, however, preclude the consideration of the zonal distribution and destructiveness of the bollworm throughout this region.

UPPER AUSTRAL ZONE.

By reference to the map (Pl. II) it will be seen that the Upper Austral zone covers a large part of the more central territory, east and west, of the United States. This zone is divided into two subdivisions, namely, the Carolinian area and the Upper Sonoran area. In the present discussion it is necessary to consider them separately.

CAROLINIAN AREA.

The Carolinian area is distinguished from the Upper Sonoran by reason of its greater humidity. It finds its western limits along the one-hundredth meridian. Throughout practically all of this area the

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[a] Insect Life, II, p. 42.

[b] Bul. 43, Minn. Agric. Exp. Sta., p. 198.

[c] Mr. E. S. G. Titus, of this Bureau, however, reports that he has taken the bollworm in Wyoming.

bollworm is well established, appearing in considerable numbers almost every year and attacking sweet corn, tomatoes, field corn, garden vegetables, ornamentals, and various other plants. Numerous reports are made of its injuries to these plants. In New Jersey, Delaware, Maryland, Ohio, Indiana, Illinois, and other States of this area, where sweet corn and tomatoes are largely grown for canning purposes, the insect is considered a pest of prime importance to these crops. Injury to field corn occurs in varying degree almost every year, often attaining considerable proportions. The character and regularity of injuries by this insect fix it as a permanent pest in this area, and it is unnecessary in this connection to cite specific examples of injury.

UPPER SONORAN AREA.

In the western or more arid portion of the Upper Austral zone east of the Rocky Mountains the bollworm, from the data in hand, appears to lose much of its importance as a pest. Sufficient data are not available to discuss the extent and character of its injuries, but the few reports indicate that during certain years it is moderately abundant and destructive to sweet and field corn.

LOWER AUSTRAL ZONE.

In the Lower Austral zone, especially the area eastward of, approximately, the one-hundredth meridian, and known as the Austroriparian, the bollworm attains its maximum abundance.

AUSTRORIPARIAN AREA.

The Austroriparian area marks, approximately, the principal cotton-growing territory of the South. While the bollworm varies much in destructiveness throughout this territory—a fact due largely to local conditions, such as differences in methods of farm practice—yet it is everywhere present, and usually in injurious numbers, on some of its numerous food plants, as corn, cotton, tomatoes, tobacco, alfalfa, and various garden vegetables. Throughout the greater part of the area the commercial culture of sweet corn is attended with the greatest difficulty by reason of the attacks of this species. In Florida and other sections of the South, where the growing of early tomatoes for northern markets is an important industry, the bollworm is yearly the source of much loss from its ravages to the early fruit. Probably nowhere in the world does the cotton bollworm become the source of more complaint than in the Austroriparian area of the United States.

LOWER SONORAN AREA.

The western and arid portion of the Lower Austral zone is designated the Lower Sonoran area. In Texas, from about the ninety-eighth

meridian westward, the bollworm rapidly becomes of less and less importance along with the diminishing annual rainfall. The further consideration of this area will be included in the next topic.

THE BOLLWORM IN THE WESTERN UNITED STATES.

Owing to the incompleteness of data on the distribution and destructiveness of the bollworm in the more Western States traversed by the Rocky and other ranges of mountains, and the consequent breaking up of the zones into small and more or less poorly defined areas, it will not be possible to indicate the relative destructiveness of the insect in this territory, except in a very general way.

No records have been found of the occurrence of the bollworm in the States of Montana and Washington. In Oregon, however, it was reported by Professor Washburn[a] as destructive to sweet corn at Corvallis, in 1889, and elsewhere in the State. It was not considered a newcomer, as it had been reported by farmers four, or even eight, years previously. These reports appear very probable, in view of the records of this Bureau of two specimens from Oregon prior to 1885, as mentioned by Riley in the Fourth Report of the United States Entomological Commission.

The bollworm was to be found in California as early as 1879, according to a note in the Pacific Rural Press of September of that year. More recently[b] the insect has been mentioned by Mr. Coquillett as feeding on various plants in that State, though no data are furnished to indicate serious injury from the pest. In Nevada, according to Prof. F. H. Hillman,[c] the bollworm is commonly injurious to sweet corn, and less frequently to tomatoes, in the western part of the State. Injury is reported[d] from Buckeye, Ariz., to corn in 1899, and its occurrence in portions of New Mexico, injuring corn and tomatoes, has been occasionally mentioned by Professor Cockerell. In Utah, according to Prof. E. D. Ball, the bollworm is a pest of considerable importance, injuring corn and other crops.

FARM METHODS IN RELATION TO BOLLWORM INJURY.

As has been elsewhere mentioned, present injury to cotton by the cotton bollworm assumes its greatest proportions in Texas, Louisiana, Indian Territory, Oklahoma, Mississippi, and Arkansas, with more or less injury in Alabama. The fact that the western part of the cotton belt should be thus afflicted, while the Carolinas, Georgia, and Florida enjoy practical immunity, is somewhat remarkable, and this

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[a] Bul. 3, Oreg. Agric. Exp. Sta., p. 6.

[b] Insect Life, I, p. 331.

[c] Bul. 36, Nev. Agric. Exp. Sta., p. 19.

[d] Bul. 32, Ariz. Agric. Exp. Sta., p. 288.

condition of affairs is apparently attributable to certain definite causes, susceptible of explanation.

It is almost an axiom in economic entomology that greatly increased planting of a crop, to the practical exclusion of all others, is followed by a corresponding increase in insect depredations on the crop thus grown. Those who have followed the development of the cotton-growing industry in the States west of the Mississippi River during the past two or three decades need not be told how extensive this has been. Quoting from the Twelfth Census:

> Of the entire crop, 34.05 per cent was grown west of the Mississippi River in 1879; 38.44 per cent in 1889, and 43.80 per cent in 1899. * * * Of the total increase of 4,099,831 acres in the decade 1890 to 1900, 3,637,398 acres, or 88.7 per cent, were contributed by Texas, Indian Territory, and Oklahoma. The increase in Texas was 3,025,824 acres; in Indian Territory, 371,987 acres; in Oklahoma, 239,569 acres. This leaves an increase of only 462,433 acres for all the other States, which was nearly reached by the increase of 440,970 acres in Alabama.

The tide of immigration which in 1850 began to move westward from the more eastern cotton States peopled this newer country largely with cotton farmers, and until recently but little attention has been given to diversified farming, corn and cotton being the principal crops grown. As transportation facilities have improved, the tendency has been to increase the farm acreage in cotton and to depend more and more on the North and West for the food supply. This extension of the cotton area and neglect of crop diversification have resulted partly from the belief that climate and soil were not adapted to the cultivation of those crops grown successfully farther north, but more largely on account of labor and economic considerations. Landowners have for the most part come to consider cotton as the only crop which might be grown on a large scale with reasonable convenience and safety to themselves, and there has thus been developed a condition of finances which has necessitated the planting, by tenants and small landowners in need of credit, of cotton as collateral for the amounts advanced.

Plantations and farms of large size are the rule, and the tenant system, therefore, finds its maximum development in the area under consideration. This fact, in connection with the large areas in cotton as compared with other crops, and the natural fertility of the soil, producing a rank, succulent plant growth, have been important factors in bringing about the present importance of bollworm ravages.

The cotton crop requires the occupancy of the ground from early in the spring until late in the fall, the growth of the plant being checked only by frost. If the fall be unfavorable, the picking may be greatly delayed, often extending through the winter and well into the following spring. Under such circumstances thorough plowing of the ground in the fall or winter, with its consequent beneficial influence in destroying hibernating pupæ, is not possible, and land is planted to cotton, often during several successive years without a thorough breaking up.

As a rule cotton crops have not received the attention necessary for their best growth and fruitfulness. This lack of necessary cultivation is more particularly noticeable with tenant farmers. The plant is thus least able to overcome insect ravages and put on additional fruit in place of that destroyed. The natural perennial habit of the cotton plant tends to make its growing season later and later for a given locality. The continued use of seed of local and often unknown origin, frequently secured from public gins, has been instrumental in producing a rank, late fruiting and maturing strain of cotton on which bollworm ravages are generally admitted to be much more severe than on earlier maturing varieties.

The principal crops grown, namely, cotton and corn, are the two preferred food plants of the bollworm, and in the absence of fall and winter plowing the insect finds conditions most favorable for its development.

In the more eastern cotton belt States conditions affecting the status of the bollworm present important differences and readily account for the unimportant character of the insect as a cotton pest in these States. The smaller size of farms does not permit of the cultivation of cotton in such large and unbroken areas; while the "weed" is smaller and less succulent by reason of a lesser fertility of the soil. The general use of fertilizers hastens the formation of fruit, so that it is more quickly out of danger of insect attack. The rotation of crops also is much more generally practiced. The three-year rotation of corn, cotton, and oats, or other crops, insures thorough plowing of the lands. Cowpeas are very generally planted in corn as it is being laid by, and often after oats, thus furnishing the bollworm moth with an abundance of food from the nectaries of the flower stalk, and they are thus not forced to the cotton fields for food. In Georgia the senior author has seen bollworm moths literally in swarms feeding in cowpeas, to the complete neglect of adjacent fields of cotton.

It would appear that there is some relation between the relative acreage in cotton and peas in the different States and the injury suffered by these States from bollworms. The following table, compiled from the Twelfth Census, of the plantings of cotton and peas for the year 1899, is of interest in this connection:

Table III.—*Comparative acreage in cotton and cowpeas, 1899.*

State.	Acreage in cotton.	Acreage in peas.	Ratio of acreage in cotton and peas.
North Carolina	1,007,020	88,407	11 to 1
Florida	221,825	17,875	12 to 1
South Carolina	2,074,081	143,070	13 to 1
Georgia	3,513,839	167,032	21 to 1
Alabama	3,202,135	91,126	35 to 1
Mississippi	2,897,920	64,490	41 to 1
Arkansas	1,641,855	31,414	52 to 1
Louisiana	1,376,254	15,190	91 to 1
Texas	6,960,367	33,947	205 to 1

It will be noted that the acreage in peas, as compared with the acreage in cotton, decreases almost in proportion to the increase in severity of bollworm injury in the respective States. In Texas, where there is but 1 acre in peas to every 205 acres in cotton, bollworm injuries are of greatest severity.

The very general practice of planting late corn for forage, silage, and other purposes is, in effect, the application of the trap-crop idea. By this practice, which has come about simply as a farm expedient, the farmers of the Carolinas, Georgia, and portions of Alabama have unconsciously greatly lessened the danger of bollworm injury to cotton by providing the insect with a succession of its favorite food plant.

RELATION OF WEATHER TO BOLLWORM INJURY.

The belief is firmly established in the minds of many cotton planters that rainy weather, especially during late July and early August, is largely responsible for severe bollworm injury to cotton. Further, the opinion is occasionally expressed that the "worm" is the direct result of such weather conditions. The fact that it is just at this time that the hardening of field corn forces the moths to the cotton fields appears to be lost sight of, and the sudden and destructive appearance of the larvæ on cotton has often been attributed to the occasional showers which may occur at this time of year. However, a belief so well established, resulting from many years of observation and experience, should have some foundation in fact, and such appears to be the case. The accurate explanation of the factors involved, however, is by no means easy, owing to the difficulty of obtaining data on a question of this kind.

As the reader will learn in the following pages of this bulletin, the bollworms, upon completing, during July, their growth in the ears of field corn, enter the soil and, after constructing a cell, become pupæ, from which, in the normal course of events, the moths or parent insects issue about two weeks later. Observations have shown that many of these pupal cells are not made with sufficient care by the larvæ to permit of the ready escape of the moth from the soil. The most common defect is that the cell is not extended upward sufficiently near the surface of the ground so that there will be but a thin crust of earth for the moth to break through in making its escape. The occurrence of a soaking rain and the consequent softening of the soil would permit the escape in perfect condition of many moths which under conditions of hard-baked soil must have perished in their pupal burrows. It has often been observed in the course of this investigation that moths were noticeably more abundant shortly after a soaking rain. This fact probably has its explanation, as above intimated, in

the increased number of moths which are able to escape in perfect condition from a moist, wet soil, as compared with a dry and harder one.

Abundance of suitable food appears to be a vital necessity for the normal longevity of the moths. Thus, during July and August moths kept without food in the laboratory lived for about six days, which was about half the length of life of females supplied with food. Further, laboratory records show that oviposition does not really begin until after the female has been able to partake of food. The food of bollworm moths during the months of July and August, under outdoor conditions, consists partly of such nectar as may be obtained from flowers, but principally of nectar from the nectaries of cotton flowers and squares, and it would appear reasonable that during periods of drought this nectar supply would be far less copious than during rainy weather. Occasional showers would at least furnish an abundance of water collected at the base of flowers and elsewhere, which the moths have been frequently observed to feed upon. So far as the adult stage of the insect is concerned, there would appear to be some foundation for the belief that the insects are more successful during rainy than dry weather.

There is but little information bearing on the influence of climatic conditions on the pupal stage of the insect except that pertaining to the effect of low temperatures, which will not be discussed here.

During the larval or bollworm stage it is most exposed to the attack of parasitic and predaceous insect and other enemies which, on the whole, are much more active during dry than rainy weather. Various species of wasps, principally of the genus Polistes, are very effective predatory enemies of the bollworm. From early in the morning until late in the evening, during fair weather, these insects may be seen busily searching the cotton plants for larvæ, and the sum total of bollworms destroyed by these hunters in the course of a single day must result in considerable pecuniary gain to the planter. Rainy weather keeps the large majority of these wasps from the fields, and the bollworms are thus permitted to develop to that extent unmolested. Other predatory enemies, as tiger and ground beetles and their larvæ, robber flies, etc., are also noticeably more active in fair than rainy weather, and the cessation of the attacks of these species during such weather is doubtless an important reason for the more serious depredations of the bollworm.

An important hymenopterous parasite of the smaller bollworms, when on cotton or other plants where they feed more or less exposed, namely, *Microplitis nigripennis* Ashm., appears, from general observations made during the season of 1904, to be out in greatest abundance during clear weather; and this is probably true of other parasitic insects, such as Tachinid and other flies.

Trelease[a] observed more than thirty years ago that during dry weather, and on the drier situations of the field, ants were much more abundant and hostile to bollworms than during rainy weather, or on the lower and more moist parts of the field. Several observers have advanced the theory that the absence, during dry seasons, of both the boll and cotton worm is largely due to the effectiveness of several species of ants in keeping them in check. The importance of this theory, in its bearing on the subject under discussion, rests on the assumption of the predatory habits of the ants. From our own observations we are not inclined to attach much importance to the work of ants, for the reason that frequent and close observations of these insects in cotton fields and elsewhere have failed to verify previous statements of their habit of voluntarily preying upon bollworm larvæ. Under certain conditions, as when provoked, several species of ants have been observed to attack and kill small bollworms, but the few instances when ants have been observed feeding on larvæ in the fields have not been free from the suspicion that the worms had been previously injured and more or less disabled, as by one of their fellows. At no time during the past two years have any of the native cotton-field ants been observed, under natural conditions, to voluntarily attack bollworms.

It remains to mention a fact doubtless of considerable importance, namely, that rains produce in the cotton plant a rapid and more succulent growth, which, by furnishing the larvæ an abundance of tender food, greatly favors their development. This and the increased food supply for the moths under these conditions, as well as the increased percentage which are able to escape from the soil, are reasons which in themselves are almost sufficient to account for the greater destructiveness. An illustration of this is to be seen almost every year in the known greater destructiveness of bollworms on "bottom-land" cotton where the soil is moist and more fertile and the weed growth stronger, as compared with the injury on the more stunted growth on uplands. It is probable that the moths are primarily attracted to the ranker cotton by reason of the greater nectar supply, and eggs are deposited on these plants during the course of their feeding.

The influence of shade, as during cloudy and rainy weather or by reason of the luxuriant growth of cotton in closely planted rows, is also apparently favorable to the larvæ, but it is to be noted that these feed readily without seeming discomfort on the exposed portions of the plants, often in the direct rays of the sun.

In the egg stage the bollworm is subject to parasitism by a minute chalcidid fly (*Trichogramma pretiosa* Riley), the importance of which in destroying bollworm eggs doubtless varies much with the character

[a] Comstock's Rept. on Cotton Insects, Washington (1879), p. 378.

of the weather. It is almost certain that these minute insects are not active during rainy weather, as they could scarcely live under such conditions. It is further probable that they are actually destroyed in large numbers by the rain, despite their efforts to secure safe retreat.

As opposed to the favorable influence of rainy weather on the bollworm by interference with the work of its natural checks must be mentioned the considerable destruction of eggs under the same conditions which are favorable to its increase in other stages. A heavy rain has the effect of washing from the plants to which they are attached many of the eggs, the great majority of which are destroyed by the combined mechanical effects of the rain and particles of soil. Frequent observations before and immediately after heavy rains leave no doubt that many eggs are thus destroyed.

The foregoing remarks have been confined to an explanation of some of the factors involved in the greater destructiveness of bollworms to cotton following rainy weather in late July and in August. The month of August, including during some seasons the last week or ten days of July, marks the period of danger from bollworms. The tendency on the part of the planters has been therefore to limit the influence of weather conditions to about this period. The insect, however, is subject to these same conditions in its several generations from early in the spring until late in the fall, and during the winter the pupæ in the ground are probably much influenced by climatic conditions. The possibility of severe injury to cotton in July and August therefore depends also on how they have been able to maintain their numbers during the balance of the year. Owing to their rate of multiplying in geometrical progression, the destruction of a pupa during the winter, or of a larva in young field corn in the spring, would diminish the possible number of bollworms ready to attack cotton in August by many thousands. Their abundance or scarcity on cotton is therefore seen to depend on other conditions than those existing during the immediate period of injury.

INJURY TO COTTON FROM OTHER CAUSES THAN THE BOLLWORM.

The known capabilities of the bollworm to injure cotton has led to its being charged with practically all forms of injury affecting the squares and bolls, aside from that done by the boll weevil, and the seriousness of its ravages has thus often been greatly exaggerated, especially by those not accustomed to examine closely into matters of this kind. As is shown on a later page, there are a few insects affecting both corn and cotton which might, from the character of their work, be mistaken for bollworms. These are, however, relatively unimportant in the extent of damage. Certain hemipterous insects, as *Calcoris rapidus* Say, *Homalodisca triquetra* Fab., and *Largus cinctus*

H.-Sch., are known to occur on cotton plants and puncture the squares and bolls more or less, but ordinarily, according to our observations, these species are not the occasion of much injury. Much more important, however, is the shedding of squares and young bolls, or their drying up on the plant, which is in no way the result of insect attack, but is a physiological trouble. Injury of this character has often been pointed out as due to bollworms, and, on the whole, it is not ordinarily distinguished by planters from the work of this insect. Interesting observations on this trouble were made by Dr. G. F. Atkinson when biologist of the Alabama Agricultural Experiment Station, and reported in Bulletin No. 41 of that station. The importance of the subject warrants the presentation from that publication of certain remarks which throw light on the character of the malady:

The shedding of bolls or "forms," or their death and drying while still attached to the plant, is very frequently a source of great loss to the cotton crop. The trouble has been long known, but one widely prevalent and disastrous form has been misunderstood. It is often confused with the work of the bollworm, with punctures made by some hemipterous insect, etc. That some of the shedding is due to the work of the bollworm is true, but the shedding referred to here is a purely physiological trouble.

During three years' observation in Alabama the author found this physiological form of shedding to be very serious. It occurs most frequently in extremes of either dry or wet weather, or during the change from one extreme to another. It may occur to some extent under normal climatic conditions, especially if the cotton plants are too thick, or the variety of cotton is one which develops a very large amount of fruit forms in proportion to the leaf surface.

During a normal period of growth the plants put out as many fruit forms as could be matured should the conditions favorable to growth continue. If a very dry period succeeds this, interfering with the supply of nutriment and moisture, there will occur a partial withholding of tissue-forming material and moisture at a very critical period in the life of the young "forms," and the tissues of the young fruit are forced into an unnaturally matured condition. The fruit, including the peduncle and often more or less of the surface tissue of the stem at its point of attachment, becomes first of a paler green color than the adjacent parts of the plant, so that a well-marked color line delimits the healthy from the unhealthy portion. In many cases the tissue is separated at this line, so that the fruit falls off completely or hangs by a few fibers to the stem. The early growing season may be exceptionally favorable for the development of a large plant with an abundance of young fruit, and if followed by even ordinarily normal conditions will result in a partial loss of this fruit. A long rainy season may also cause the young bolls or forms to fall, the soil being so saturated with water as to interfere with root absorption, and the assimilative activity of the leaves will also be disturbed.

Observations have been made at different times bearing on the amount of injury from the bollworm as compared with that from other causes. The following table made up from observations by Mr. C. R. Jones indicates the character of results in general. Squares were picked at random from the cotton plants in passing through the fields. and afterward examined and classified. Five hundred squares were picked from each field.

FIG. 1.—FIELD OF YOUNG CORN AT PARIS, TEX., AT ABOUT THE AGE IN THE SPRING WHEN IT BECOMES ATTRACTIVE TO MOTHS FOR OVIPOSITION (ORIGINAL).

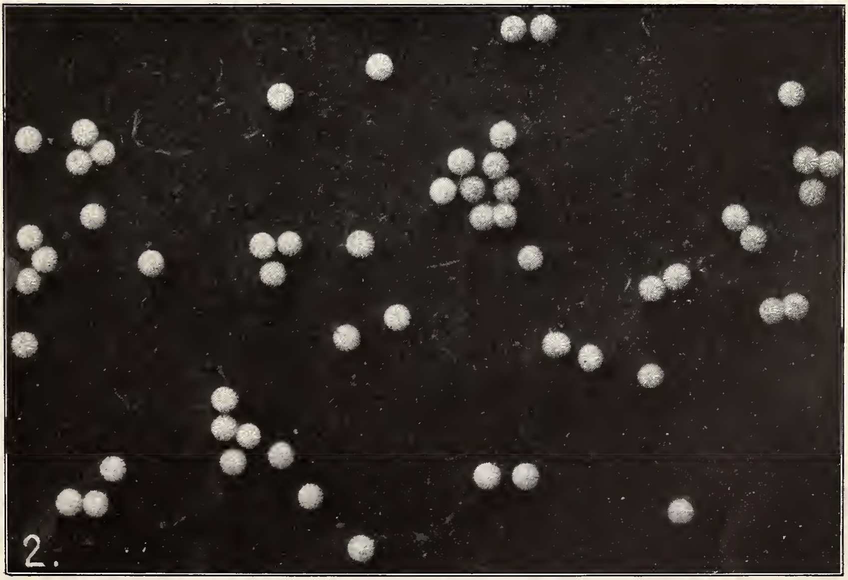


FIG. 2.—A NUMBER OF BOLLWORM EGGS ON A PIECE OF BLACK PAPER, ENLARGED ABOUT SEVEN TIMES (ORIGINAL).

TIP OF EAR OF CORN, SHOWING BOLLWORM EGGS ON THE SILKS.

In the upper right-hand corner are a few eggs, on silks, enlarged about four times (original).

TABLE IV.—*Injury to cotton by bollworm and other causes.*

Date.	Place.	Number of good squares.	Number of squares injured by boll-worm.	Number of squares injured from all other causes.	Remarks.
July 14	Wharton, Tex	168	1	331	Largely injured by boll weevil.
July 16	Morgan, Tex	472	3	25	
July 20	Comanche, Tex	483	....	17	
July 24	Groesbeck, Tex., field No. 1	411	37	52	Some injured by weevil.
July 25	Groesbeck, Tex., field No. 2	454	26	20	
July 27	Gilmer, Tex	489	6	5	
Aug. 4	Mineola, Tex., field No. 1	446	23	31	
Aug. 5	Mineola, Tex., field No. 2	444	21	35	
Aug. 6	Providence, Tex	342	91	67	
	Total	3,709	208	583	

Average per cent injured by bollworm 4.6
Average per cent injured from other causes 12.9

EARLIER INVESTIGATIONS OF THE DEPARTMENT OF AGRICULTURE.

The investigation of the cotton bollworm was one of the first entomological problems undertaken by the Federal Government. With the appointment of Townend Glover as entomologist to the division of agriculture of the Patent Office on June 14, 1854, an investigation of the insects injurious to the cotton plant was immediately begun. In September of that year Mr. Glover visited plantations near Columbia, S. C., and made many interesting and important observations on the bollworm, as well as on other cotton insects. Many points in the life history and habits of this insect were determined, and at this early date the striking similarity between the bollworm and corn-ear worm was pointed out. But it should be here noted that their identity had been practically accepted by Mr. J. W. Boddie, of Jackson, Miss., in July, 1850, as a result of his own observations. A brief report on the bollworm was made by Mr. Glover in the Patent Office Report for 1854, pages 60 and 64. The same insect is also treated under the caption of "The Corn Worm," on page 69 of this report, many of the essential points in regard to its habits and injuries to this plant being set forth. As bearing on the control of the bollworm on cotton at this time, Mr. Glover states that, according to Mr. B. A. Sorsby, of Columbia, S. C., when the corn on two or three plantations was carefully "wormed," the bollworms did not make their appearance that season on cotton, although on neighboring plantations great injury was inflicted. Mention is made of a recommendation to light fires in various parts of the plantation at the time when the first moths make their appearance, and the statement is made that the moths are attracted to lights and will be killed in great numbers. Successful experiments in killing moths by attracting them to a mixture of vinegar and molasses are reported as made by Colonel Sorsby a year or two previous.

Concerning the control of this insect on corn, Mr. Glover states:

> The method to extirpate these insects would be to devise some method of destroying the first brood of the perfect moths before the eggs are deposited, either by means of lights or the vinegar and molasses on plates, as suggested by Colonel Sorsby.

In the Patent Office Report for 1855 Mr. Glover gives further observations on the bollworm and again refers to the remedial measures previously mentioned. The possibility of poisoning the vinegar and molasses solution to kill the moths is suggested. Mention is made of the dissection of a single bollworm moth by Dr. John Gamble, of Tallahassee, Fla., which contained at least 500 eggs.

In the Monthly Report of the Department of Agriculture for 1866, page 282, Mr. Glover, under the title "Insects Injurious to the Cotton Plant," again presents previously determined facts concerning the bollworm without adding any points of importance. Three generations at least are said to occur annually in Georgia. Nothing is added to the remedial measures previously indicated.

Aside from frequent notice of injury from the bollworm in various parts of the cotton belt in the Monthly Reports from 1867 to 1876, Mr. Glover's work on this species seems to have closed in 1865. Mention should, however, be made of his "Manuscript Notes from my Journal, Cotton and the Principal Insects, etc., Frequenting or Injuring the Plant in the United States," a collection of illustrations of this class of insects bearing date of 1878 and issued for private distribution. Although Mr. Glover determined many valuable points concerning the life and habits of the bollworm, but little progress was made in the way of determining effective means of control. His recommendations for the use of sweets and fires to attract moths to their destruction have subsequently been shown to be of no practical value.

The next important work of the Department pertaining to the bollworm was begun July 1, 1878, in connection with an investigation of the insects injurious to the cotton plant, ordered by Congress. This work was in charge of Prof. C. V. Riley until the date of his resignation as Entomologist of the Department of Agriculture, May 1, 1879, when the continuance of the investigation fell to Prof. J. H. Comstock, appointed to the vacancy. A special report was ordered by Congress from the Department of Agriculture on insects affecting the cotton plant, and this was submitted by Professor Comstock November 14, 1879, entitled "Report on Cotton Insects," a work of 511 pages, dealing with the cotton-leaf worm (*Alabama argillacea* Hbn.) and the cotton bollworm, 28 pages being devoted to a consideration of the latter insect.

At this time, also, an investigation of the bollworm was in progress in connection with a study of cotton insects by the United States Entomological Commission, working independently of the Department of

Agriculture. The results of the investigation of the United States Entomological Commission on cotton insects are contained in the Fourth Report of this Commission, by Prof. C. V. Riley, a volume of about 600 pages, of which 29 are devoted to the bollworm. While the report referred to was issued in 1885, the work of the Commission was practically completed in 1881.

From these reports much was gained in knowledge of the injuries, life history, and habits of this pest, and sound remedial measures are suggested. The character and scope of the work may be best indicated by the presentation of the topics discussed in the report of Professor Comstock:

The bollworm: Importance of the subject; Natural history; Nomenclature; Geographical distribution; Food plants; The egg; The larva; The chrysalis; The moth; The number of eggs; Influence of weather. *Remedies:* Natural remedies; Artificial remedies; Topping; Poisoning; Handpicking; Destruction of the chrysalids; Destruction of the moth.

The principal points presented in this report are the wide geographical distribution of the bollworm moth; the practically omnivorous habits of the larvæ; the determination of the fact that the eggs of the bollworm are distributed quite generally over the plant, as foliage, stalk, square, and flower, and the feeding of the young larvæ on more or less exposed portions of the plant near the place of their birth; the hibernation of the pupæ in the soil; habits of the parent moth; the determination of five annual generations for central Alabama; the fact of more serious injury during wet seasons; the possibility of killing bollworms by poisoning; the possible utility of corn as a trap crop, and the usefulness of fall plowing in more northern latitudes for the destruction of hibernating pupæ.

Many of these points were not original with this investigation, as, for instance, the recommendation of the possible utility of corn as a trap crop in protecting cotton. This idea appears first to have been suggested by Mr. E. Sanderson in 1858, as a result of his belief in the identity of the corn worm and bollworm, and his recommendations are set forth in the American Cotton Planter of 1858. Professors Riley, French, and others had also previously determined many of the points here presented. The report of the United States Entomological Commission on the bollworm, by Professor Riley, adds but little to our knowledge of the pest as presented in the report of Comstock, and need not be considered in detail.

A special investigation of the bollworm was provided for by Congress in 1890, and this work was begun July 1 of that year, by Mr. F. W. Mally, working under the direction of the Entomologist, Professor Riley. The chief object of this investigation was to conduct further experiments with remedies, as well as to verify the value of those already employed, and incidentally to ascertain new facts

concerning the life history and habits of the insect, and to verify or disprove what had been previously written concerning these points. The results of this investigation by Professor Mally are presented in Bulletins 24 and 29, old series, of the Division of Entomology, and were issued in 1891 and 1893, respectively.

Many detailed observations on the injuries to corn, cotton, and other plants were made, and a systematic series of experiments was conducted with various insecticidal substances in order to determine their possible value in bollworm control. The value of corn as a trap crop is demonstrated and a definite plan is presented for its utilization by planters. Experiments with bacterial diseases were conducted, and the uselessness of attempts to attract moths to lights and poisoned sweets, as previously recommended, is pointed out. The reports together cover 123 pages, and bring together the important facts then known concerning the cotton bollworm and present for the first time results of any considerable experimental work.

Frequent mention has been made of the bollworm as injuring cotton, corn, tomatoes, or other crops in the bulletins and reports from the office of the Entomologist of this Department, and recently (1896) a full account of this species, by Dr. L. O. Howard, has been distributed in Bulletin 33 of the Office of Experiment Stations,[a] which was issued in revised form in 1897 as Farmers' Bulletin 47, "Insects affecting the cotton plant."

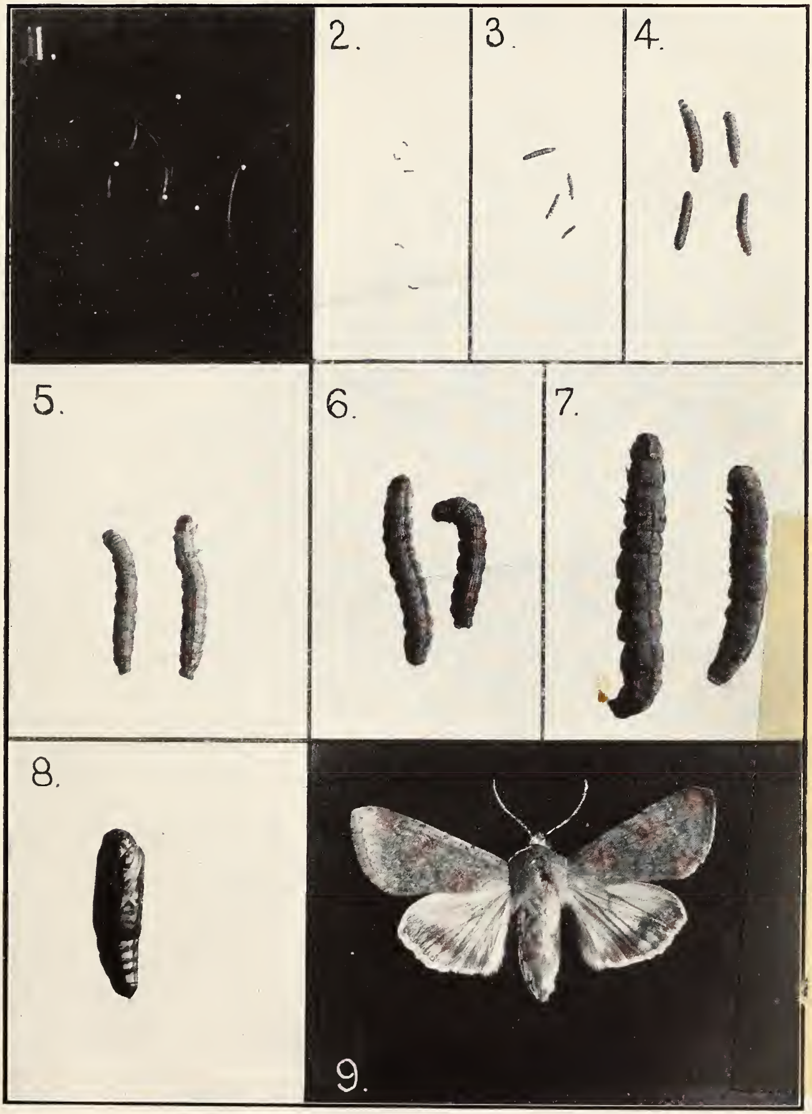
In spite of the work of the Department on the bollworm, but little progress had been made by the planters in its control. The recent increase of the ravages of the pest in certain parts of the cotton belt, notably in Texas, led to provision by Congress for another investigation, and the present paper is a final report on this the fourth specific investigation of the species. The present investigation was begun in the spring of 1903, and continued to December 31, 1904. Reports of field work have already been published in Farmers' Bulletins 191 and 212 of this Department.

LIFE HISTORY.

SUMMARY.

The eggs of the bollworm (Pl. III, fig. 1) are deposited by the bollworm moth upon the food plants of the larvæ, which are preferably corn and cotton, or less commonly tomato or tobacco. Each female may lay from 500 to 3,000 eggs, which she deposits singly in a more or less promiscuous manner over the plants, more especially on the silks of corn and the squares of cotton. During the warmer parts of summer the eggs hatch after two or three days and the larvæ begin feeding. On corn they attack the tender bud in the spring and the

[a] The Cotton Plant, pp. 328–333.



STAGES IN THE LIFE HISTORY OF THE BOLLWORM.

Fig. 1, Eggs on corn silks; figs. 2–7, larvæ, first to sixth instars, respectively; fig. 8, pupa; fig. 9, adult female moth—all figures enlarged one-fourth (original).

tassel and milky ear later in the season; while on cotton, during August and September, the squares and the bolls are eaten. The larvæ bore directly into the squares and bolls through a small orifice which they make, and eat out a varying portion of the contents. This causes the squares to flare and drop from the plants, and partially or entirely destroys the bolls. The larvæ (Pl. III, figs. 2–7) have molted five times and are completely grown in about two weeks during hot weather, at the end of which time they leave the food plant and burrow into the soil to pupate. In this stage (Pl. III, fig. 8) another two weeks is passed before the adults (Pl. III, fig. 9) of the next generation emerge. After the latter have been out for several days egg laying again begins. The larvæ and moths are extremely variable in color and markings, the former varying from a pale green through pinkish to dark brown. During the course of the summer in the cotton belt there are from four to six generations, while to the north the number decreases to two or three in the Central States and probably to a single one in Canada. The bollworm passes the winter in its earthen cell beneath the surface of the soil, emerging as a moth early in the spring. During the middle of the summer in the cotton belt the entire life cycle occupies from 30 to 35 days only, while in the spring and fall, and also in northern localities, it may extend over as much as two months.

THE EGG.

DESCRIPTION.

The eggs of the bollworm are small white objects, scarcely one-fiftieth of an inch in diameter. On account of their rather pale color they are not very difficult to detect when deposited on green foliage or on dark-colored corn silks, but on the paler silks one must look very closely before they can be seen. A number of eggs are represented considerably enlarged on Plate IV, figure 2; also see text figure 2. Following is a more minute description:

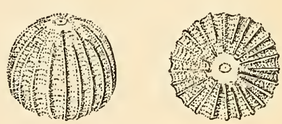


Fig. 2.—Egg of bollworm; side and top views (original).

Width, 0.48 mm.; height, 0.50 mm. Shining, waxy white, faintly tinged with yellowish. The form is almost dome-shaped, except that it is slightly narrower at the extreme bottom and widest about the basal third. Base flat and apex obtusely rounded. Micropyle elevated, somewhat conical; its sides finely longitudinally grooved; the margin circularly roughened.

The sculpture is rough and consists of fourteen primary polar ribs which converge toward the apex, where they become obsolete. Between these is a series of secondary ribs which are more irregular, often bifurcate at the apex or joining the primary ribs. Spaces between the ribs transversely furrowed by a series of oval depressions, between which are fine transverse carinæ. These latter do not rise as high above the surface as the polar ribs and are much more delicate.

The shell is rather tough, and, although the eggs are quite delicate, they are not very easily crushed.

OVIPOSITION.

The eggs are laid usually in the early part of the evening, between sundown and dark. During the summer months the moths are not infrequently seen flying and ovipositing on cloudy or dark days, or very rarely even on bright ones, but this is the exception. Egg laying begins some two or three days after emergence from the ground if the female has been fertilized by the male; otherwise it may be delayed for some days longer. Quite often solitary females kept in confinement in the laboratory deposited large numbers of infertile eggs, but this probably rarely happens in nature.

On account of the different circumstances surrounding oviposition on corn and cotton, the process on these respective plants will be considered separately.

OVIPOSITION ON CORN.

Although the moths which appear in early spring from hibernating pupæ lay a few scattering eggs on other plants, such as various garden vegetables, by far the greater number of them confine their oviposition to young field corn. As soon as the corn has attained a height of from 10 to 16 inches oviposition begins, but it does not become general until the plants are somewhat more advanced, like those shown on Plate IV, figure 1. The earliest records in Texas for 1904 are: Victoria, March 26; Beeville, March 28; Austin, March 31; Calvert, April 2; Terrell, April 22; Paris, April 20. After these dates the eggs become gradually more abundant, although variable in number, scarcely ever being entirely absent in corn fields until the ripening plants later in the season become no longer attractive to the moths.

The following table, compiled by Mr. F. C. Bishopp from counts made on young corn during the spring of 1904, shows the average deposition at that time:

TABLE V.—*Oviposition on early corn.*

Date.	Locality.	Height of plant.	Number of plants examined.	Total number of eggs.	Approximate number eggs per plant.
1904.					
Apr. 23	Corsicana, Tex	1½ to 2 feet	200	66	0.33
Apr. 24	Hempstead, Tex	1 to 4 feet	150	383	2.5
Apr. 25	Houston, Tex	1½ feet	10	0	0
Apr. 26	Victoria, Tex	1 to 3 feet	150	22	0.14
Apr. 27	San Antonio, Tex	2 to 3 feet	125	40	0.32
Apr. 28	Waco, Tex	8 inches to 2 feet	125	40	0.32
Apr. 29	Arlington, Tex	1 to 1½ feet	125	32	0.25
May 3	Paris, Tex	1 to 2 feet	150	150	1

These records are practically the first which show any considerable number of eggs present. Deposition throughout the remainder of the season is shown in the two following tables, one from Calvert, Tex.,

from counts made by Mr. G. H. Harris, and the other from Pomona, Ga., from counts made by Mr. Mark Riegel. In each case twenty plants were examined at an observation, and, as the corn had been planted at regular intervals, plants in fresh silk could be chosen in most cases.

TABLE VI.—*Comparative oviposition on corn throughout the season.*

CALVERT, TEX.

Date.	Number eggs per plant.	Date.	Number eggs per plant.	Date.	Number eggs per plant.	Date.	Number eggs per plant.
1903.		1903.		1903.		1903.	
May 4	0.66	June 17	0.25	July 29	23.50	Sept. 9	11.80
May 26	.00	June 24	.65	Aug. 5	1.80	Sept. 16	4.90
May 29	.00	July 1	1.25	Aug. 12	42.00	Sept. 23	2.20
June 3	.00	July 15	10.30	Aug. 19	15.60	Oct. 3	1.10
June 5	1.40	July 18	.75	Aug. 26	2.75	Oct. 7	.55
June 10	.40	July 22	7.00	Sept. 2	25.25	Oct. 14	.50

POMONA, GA.

Date.	Number eggs per plant.	Date.	Number eggs per plant.	Date.	Number eggs per plant.	Date.	Number eggs per plant.
1903.		1903.		1903.		1903.	
May 30	1.15	July 4	20.40	Aug. 8	1.45	Sept. 12	9.35
June 6	2.90	July 11	7.60	Aug. 15	2.60	Sept. 19	8.85
June 13	.35	July 18	5.50	Aug. 22	18.20	Sept. 26	6.60
June 20	.55	July 25	2.30	Aug. 29	14.30	Oct. 10	5.10
June 27	2.45	Aug. 1	1.65	Sept. 5	16.90	Oct. 24	.60

These tables are quite irregular and do not show the dates of maximum oviposition for each generation as well as might be hoped, but the data therefrom will be referred to later, in their bearing on the number of generations during the season. No doubt a great proportion of these discrepancies are due to local weather conditions and to the variable maturity of the corn plants at the time the eggs were counted.

For comparison with Table V another one, compiled from records made by Mr. C. R. Jones in the season of 1904, is given herewith:

TABLE VII.—*Oviposition on corn in silk, Texas, 1904.*

Date.	Locality.	Number of plants examined.	Condition.	Eggs on— Upper side leaf.	Underside leaf.	Silks.	Sheath.	Tassel.	Stalk.	Total.	Average per plant.
1904.											
July 15	Wharton, Tex	25	Silking	901	259	1,053	22	14	0	2,249	89.9
July 24	Grossbeck, Tex	25	5 feet; no silks	97	16			0	0	113	4.52
July 26	Gilmer, Tex	25	Silking	11	5	85	4	0	0	105	4.2
July 30	Quinlan, Tex	50	Tasseling	374	14			22	137	547	10.94
Aug. 11	Ben Franklin, Tex	20	Silking	306	77	456	44	137	236	1,256	62.8
Aug. 16	Paris, Tex	10	do	242	36	338	41	148	184	989	98.9
Aug. 19	Quinlan, Tex	25	do	234	11	265	27	60	81	678	23.1

These records are in sharp contrast with those of Table V, showing a general average of 37 eggs to the plant instead of a little less than 1 egg to each plant. The largest number of eggs observed during 1904 was 989 on 10 plants, or nearly 100 per plant. Some counts made during 1903 exceed by far those for 1904, and are also given for comparison.

Table VIII.—*Oviposition on corn in silk, Texas, 1903.*

Date.	Locality.	Number of plants examined.	Condition.	Eggs on— Leaves.	Silks.	Sheath.	Tassel.	Total.	Average per plant.
1903.									
May 3	Victoria, Tex	5	Silking	210	1,106	284	121	1,721	344
Aug. 21	Willspoint, Tex	3	.....do	830	511	122	660	2,123	707
Sept. 4	Calvert, Tex	5	.....do	553	633	241	307	1,734	347

From this great number of eggs most likely only two or three larvæ would succeed in attaining full growth and pupating. From these same tables a comparison can be made as to the proportion of eggs laid on different parts of the plants. In every case where silks were present, these bore the largest number of eggs in the following ratio to the other parts of the plant:

Table IX.—*Distribution of eggs on different parts of corn plant.*

	Upper side of leaf.	Lower side of leaf.	Silks.	Sheath.	Tassel.	Stalk.
1904:						
Number	1,694	388	2,197	138	359	501
Per cent	32.3	7.3	40.8	2.6	6.8	9.5
1903:						
Number	1,593	....	2,250	647	1,088	(*a*)
Per cent	27.1	....	40.3	11.2	19.5	

a Not counted.

This proportion varies greatly under different conditions, but the above is quite reliable. Larvæ from the immense number of eggs laid upon the stalk, sheath, and leaves must inevitably perish, as do also the greater proportion of those laid upon the silks. The significance of this fact will be dwelt upon in the consideration of corn as a trap crop.

Time and manner of oviposition.—Oviposition takes place usually between sunset and dark, often continuing much later, and frequently moths have been observed to lay on corn and cotton at other times of the day. In the case of corn, the silks are usually chosen first if these are present on the plant; the moth momentarily alights upon the tip end of an ear, bends the abdomen sickle-shaped beneath her and moving the tip about among the silks, deposits several eggs. (See Pl. V.) After this process, which requires only a few moments, she will usually fly away

often returning after several seconds to repeat the operation on the same ear. Then flying from ear to ear the oviposition continues, with an occasional visit to other parts of the plant to lay on the tassel, leaf, or stalk. Some moths show much less steadiness of purpose and fly about much more irregularly, ovipositing promiscuously on all parts of the plant.

When cowpeas are present between the rows of corn, especially in fields of June corn in Texas, and very generally in field corn in other Southern States, they receive a number of the eggs, the moths feeding on the peas at intervals between the periods of oviposition. The advantage of planting cowpeas in corn is thus evident, for the moths do not leave the corn fields as they would if food were scarce, and oviposition is confined largely to the corn. If food is not to be had in the corn fields the moths are compelled to move about in search of it, many of them flying to cotton fields, where food is always to be found if the plants are "squaring" or blooming.

OVIPOSITION ON COTTON.

As may be gathered from the foregoing, oviposition on cotton does not begin until the season is well advanced. Owing to the very suitable condition of field corn for oviposition early in July, when the maximum number of moths of the second generation are laying eggs, but few of these moths oviposit on cotton. The resulting larvæ from the small percentage of eggs which are thus laid may, however, cause the destruction of a few of the earliest squares. By the time the third generation of moths has begun to emerge, which is about the first of August in northern Texas, the field corn has begun to dry and the ears to harden, so that it is no longer attractive either for food or for oviposition. The moths are now attracted by the food offered by the nectaries of the cotton plants in the adjacent fields and desert the ripening corn almost entirely.

Time and manner of oviposition.—The process of oviposition is not continuous, but is varied by alternate periods of feeding and resting. As soon as twilight begins, the moths commence to leave their hiding places and fly about. At first their principal desire seems to be for food, and they fly from plant to plant feeding on the drops of moisture on the flowers and at the nectaries on the squares. Soon periods of egg-laying and resting are interpolated and later oviposition goes on rather steadily. The moths seem to fly about almost without purpose and to lay eggs wherever they happen to alight if they can obtain a firm foothold. This last seems to be rather important, for most of the failures to lay were noticed on the upper sides of the leaves, where it is difficult for the moths to catch hold with their tarsi. The abdomen is bent sickle-shaped beneath the thorax and the eggs pressed against the desired spot with the ovipositor. Quite often several hasty

attempts are made before an egg is laid. A strong, healthy moth, however, does not often fail to lay. From one to two seconds are usually required for each deposition. When possible the body is held either with the head up or horizontal when ovipositing, although when feeding the body may be turned at almost any angle without apparent inconvenience to the moth.

In order to obtain the foregoing data regarding oviposition on cotton some 34 moths were followed in the field at dusk, and the portion of the plants upon which eggs were laid was carefully noted at each deposition. Most of these records were made between 7.15 and 8 o'clock in the evenings during the first week of August. At that time the moths were so common that the greatest difficulty in following them was to avoid confusion of the observed moth with others in close proximity.

The appended table gives the individual records of a few of the moths, together with the totals for the entire lot of 34 moths.

TABLE X.—*Distribution of eggs on the different parts of the cotton plant.*

Part of plant.	Individual records of 11 moths.											Total of 34 moths.	Per cent.
Lower surface of leaves	7	8	5	19	18	11	29	3	7	1	14	191	16.7
Upper surface of leaves	7	14	6	8	9	16	23	3	13	5	25	194	17.0
Squares	9	12	21	28	35	32	37	8	24	2	31	326	28.5
Growing tips	8	4	2	3	10	0	0	2	0	1	0	46	4.0
Flowers	2	11	8	7	29	2	2	4	1	0	5	110	9.7
Stems	2	1	3	3	3	4	11	1	7	3	2	64	5.6
Petioles	0	4	1	8	1	0	0	0	0	1	0	29	2.5
Bolls	7	1	4	2	5	25	35	0	4	0	2	120	10.5
Weeds	0	0	3	0	6	1	0	0	0	2	0	20	1.7
Objects on ground	0	0	1	2	2	3	1	0	0	0	0	21	1.8
Dead leaves	0	0	3	4	2	0	1	0	0	0	0	20	1.7
Total eggs laid	42	55	57	84	120	94	139	21	56	15	79	1,141	......
Time observed, in minutes	8	8	15	31	26	23	65	2	20	10	20	474	......
Number of plants visited	60	50	25	149	40	80	120	15	70	81	10	1,175	......

In all, the deposition of 1,141 eggs is recorded upon 1,175 plants. The very close correspondence in numbers might suggest that one egg is usually laid to a plant by each moth, but this is not true, as many receive none at all and others a considerable number. A total time of 28,440 seconds was occupied, which gives a probable average of twenty-five seconds between two successive depositions, and allows for the oviposition of some 280 eggs each evening during a period of two hours. This is not far from the average obtained from observations on moths laying in confinement. While this may be a good general average, it is inapplicable to any special case on account of the great individual variation among different moths.

Distribution of eggs on cotton.—More eggs are laid upon the squares than upon any other part of the plant except the leaves, although only 28.5 per cent of the entire number are so placed. The fact that

71.5 per cent are deposited elsewhere than on the squares has a very important bearing on the question of poisoning the young larvæ, and will be referred to again in the following pages of this bulletin. It is quite possible that the large number of eggs laid upon the squares is accidental and due to the attraction offered by them on account of the nectaries at which the moths feed. At any rate, they appear to oviposit indiscriminately wherever they happen to alight on the plant.

It is by no means unusual for a moth to oviposit occasionally on dried leaves or sticks beneath the plants, or even on the bare surface of the ground itself. It appears that old and worn females do this more often than strong and healthy ones.

OVIPOSITION ON OTHER PLANTS.

The remarks on oviposition would not be complete without some reference to the great variety of plants on which the eggs are laid. The following table contains the records of the eggs found on miscellaneous plants during the seasons of 1903 and 1904:

TABLE XI.—*Record of eggs found on miscellaneous plants, 1903–4.*

Date.	Locality.	Plant.	Remarks.
Apr. 15	Ladonia, Tex	Rosebuds	Several eggs (in cemetery).
Apr. 20	Victoria, Tex	Rosebud	A single egg.
Apr. 20	Greenville, Tex	do	Do.
Apr. 30	Hetty, Tex	*Allium canadense*	Numerous, 3 to 4 on each head.
May 1–2	do	do	A few.
May 28	Paris, Tex	Tomato	8 eggs on 15 plants.
May 28	Victoria, Tex	*Sida* sp.?	A single egg.
July 20	Paris, Tex	Tobacco (buds)	A few.
July 21	do	Okra	1 on a dead flower.
July 15	do	Cowpeas	Very scarce on the plants.
July 15	do	*Amarantus spinosus*	1 to a plant.
July 16	do	*Solanum mammosum*	2 or 3 to a plant.
July 18	do	*Amarantus* sp.?	A single egg.
July 24	do	*Asclepias tuberosa*	Scarce, 2 on 20 plants.
July 24	do	*Euphorbia corollata*	A single egg.
July 29	do	*Amarantus* sp.?	Do.
Aug. 1	do	Johnson grass	Do.
Aug. 1	do	*Asclepias tuberosa*	A few.
Aug. 3	Calvert, Tex	Millet	17 eggs on 14 heads.
Aug. 3	Paris, Tex	Crab grass	A few.
Aug. 3	do	Osage orange	A few on leaves of small bush.
Aug. 3	do	Carpet weed	Quite numerous.
Aug. 4	Calvert, Tex	*Datura stramonium*	Rare.
Aug. 4	do	Seedling bindweed	Neglects cotton to find it.
Aug. 4	do	Cocklebur	A few.
Aug. 5	Paris, Tex	Grass	3 eggs on many plants.
Aug. 5	do	Okra pods	Rather abundant.
Aug. 5	do	*Asclepias tuberosa*	3 seen.
Aug. 7	Calvert, Tex	Virginia creeper	A single egg.
Aug. 7	do	*Ipomœa* sp.?	Lays freely.
Aug. 7	do	Sedge grass	1 egg on a blade.
Aug. 10	Paris, Tex	Peach tree	A single egg.
Oct. 6	do	Rosebud	Do.

In addition to the above, the following plants were noted bearing bollworm eggs, the dates of observations not being recorded: *Canna indica*, *Nicotiana repanda*, alfalfa, beans, sorghum, Milo maize, *Stachys agraria*, and *Panicum texanum*.

Some 32 plants on which eggs have been found, or upon which moths have been observed to oviposit, are included in this list. A number of these are present as weeds in corn and cotton fields and the eggs deposited are more likely laid on account of proximity than otherwise. In the case of the wild-onion flowers and rosebuds it is probable that the scarcity of food at such times (April and October) attracts them to these plants. Indeed, roses in gardens and cemeteries seem to be the first plants chosen for oviposition early in the spring. Oviposition on alfalfa, tobacco, etc., is by no means accidental, as the larvæ thrive well on these plants. The number of miscellaneous plants is sufficient to show, however, that under certain conditions no very careful selection is exercised by the female in ovipositing.

It must be mentioned that garden vegetables were at all times very free from bollworm eggs, especially in the spring and fall. This is at variance with the records of a number of observers, who have found larvæ common on such plants.

The occurrence of larvæ on miscellaneous plants will be considered on a later page.

NUMBER OF EGGS LAID BY A SINGLE MOTH.

Numerous moths were kept under observation at various times during the season to determine the number of eggs which would be deposited under different conditions.

Observations on early spring moths in the northern part of Texas seem to indicate that the number of eggs laid by them is rather small, averaging only 415 for each moth of a series of ten which were kept in the laboratory. At Victoria, however, in the southern part of the State, moths developing from overwintered pupæ averaged over 1,200 each for a series of five moths.

Table XII.—*Daily oviposition records of moths.*

Locality.	Began to lay.	Died.	Egg-laying record on consecutive days.													Total.
Paris, Tex	May 13	May 18	36	260	50	10	130	...	...	...	...	...	...	...	...	486
Do	May 12	May 19	10	42	19	8	78	270	10	...	...	...	...	...	...	437
Do	May 12	May 20	48	157	159	66	38	23	32	62	...	...	...	...	...	585
Victoria, Tex	Apr. 25	May 4	147	140	165	100	246	152	64	6	0	105	...	...	...	1,125
Do	May 10	May 14	556	245	184	141	92	...	...	...	...	...	...	...	...	1,218
Do	May 9	May 16	671	441	405	189	113	148	76	116	...	...	...	...	...	2,159
Do	May 7	May 19	404	107	0	0	148	50	45	26	32	26	8	50	9	905
Do	May 7	May 13	74	85	148	193	115	117	98	...	...	...	...	...	...	830
Paris, Tex	July 16	July 17	548	777	...	...	...	...	...	...	...	...	...	...	...	1,325
Do	July 18	July 27	3	11	23	15	29	60	33	53	20	50	...	...	...	297
Do	July 23	Aug. 1	780	542	404	337	251	221	71	95	12	5	...	...	...	2,718

General average for each moth, 1,098.

It will be noticed that there is nearly always a gradual decline in the number of eggs laid during each succeeding day. In the case of a few moths, more than one day shows a considerably greater oviposition than the others, the number of eggs rising to one maximum, decreasing, and then rising again, thus resulting in an irregular curve,

like the one shown in figure 3, A. In others the egg laying gradually rises to a maximum and then declines, as shown by B, of the same figure.

DEPOSITION OF INFERTILE EGGS.

All of the data given above are records of deposition of fertilized eggs. In the case of one female which had not mated and was hence laying infertile eggs, 1,723 were deposited, showing that the growth of eggs in the ovaries must apparently go on without any reference to fertilization.

EGGS REMAINING IN THE OVARIES AT DEATH.

In nearly all female moths at death there are in the egg tubules of the ovaries a number of fully formed eggs. This number varies from a very few to over 300 in different individuals. About 70 may be

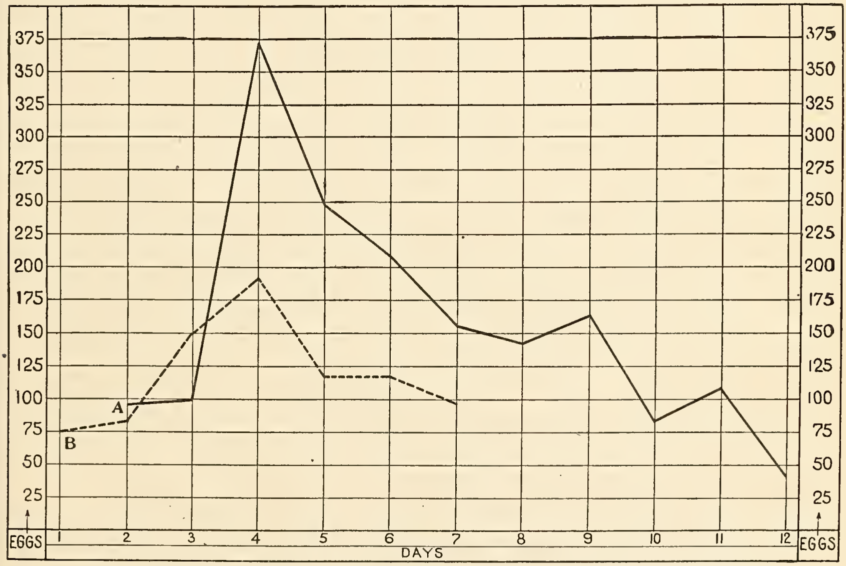


FIG. 3.—Diagram showing, A, regular and, B, irregular oviposition curves (original).

considered a fair average. Besides, there are in the ovaries a number of much smaller eggs, in which the yolk has not yet been formed. These "potential" eggs are much more numerous in females which have laid comparatively few eggs during life, and fewer in others which have deposited the full number, varying thus from 2,000 to only 50 or less.

EFFECT OF FERTILIZATION ON EGG LAYING.

Some interesting facts bearing on this matter were observed by Mr. Girault in the laboratory. Several females which had been depositing infertile eggs were allowed to mate with males, and an accelera-

tion in oviposition was at once apparent. Following are the oviposition records for each night, the time of fertilization being marked by the separating vertical line.

TABLE XIII.—*Effect of fertilization on egg laying.*

	Infertile eggs.					Fertile eggs.									
Moth No. 1	41	50	45	35	23	894	71	227	150	26	36	33	34	17	3
Moth No. 2	....	....	3	4	7	337	122	27	7	40	20	....	....	....	..
Moth No. 3	....	31	209	180	293	1,570	619	200	....	....	....	....	....	....	..

CHANGES IN EXTERNAL APPEARANCE.

The original uniform white color of the egg persists for a period of about fifteen hours. At the end of this time the upper third has usually acquired a tint which is noticeably more yellowish than the rest of the egg. The lower part of this yellowish portion gradually darkens until, about thirty hours after the egg is laid, it has become reddish or brownish. This brownish color deepens until, at the end of thirty-six hours, it is quite distinct, even to the naked eye. The outlines of the band are often broken or irregular and an additional reddish spot, much less evident than the band, can now usually be seen near the micropyle. When about forty hours have elapsed, the whole egg has acquired a dull appearance, and the pigmentation of the brownish band is also a little deeper. After this the whole egg rapidly becomes dusky four or five hours before hatching and the brown zone is obscured.

EMBRYONIC DEVELOPMENT.

In order to connect the real development of the egg with the series of external changes indicating its growth, it may be well to summarize briefly the embryonic development.

The egg is fertilized shortly before it is laid and development begins immediately. After about twelve hours the blastoderm is completely formed and the beginning of the germ band several hours later causes the appearance of the pale brownish ring when the egg is from fifteen to eighteen hours old. The development of the embryo and the formation of the appendages during the next twenty-four hours are indicated by the deepening of the color. Finally, the disposition of the pigment in the chitinous skin and tubercles causes the blackening of the egg just previous to hatching.

HATCHING.

The head of the fully developed embryo larva is quite plainly to be seen through the eggshell, as is also more or less of the coiled body. The head is now directly under the micropyle, and the body of the larva extends backward with its dorsal surface pressed against the egg-

shell. It follows the shell thus down the side, across the bottom and up the other side, until the anal prolegs at the posterior end of the body are just beneath the head. The embryo, in making its escape, bites viciously with its mandibles at the hard, tough membranes of the egg, and gradually the spot weakens and the head of the larva suddenly bursts through. It can now easily enlarge the hole until it is of sufficient size to crawl through. Once this is done, the larva is free from the egg in about two minutes. The whole process, from the first attempt to pierce the egg membrane until the larva is excluded, requires but a few minutes. In two cases where the exact time was noted it was thirteen and sixteen minutes, respectively.

The exit hole is usually large, with very ragged edges, situated on one side of the egg between the base and apex. The empty shell is of a translucent white, with a distinct purplish iridescence seen in certain lights, more especially when viewed against a dark background. It retains its original shape.

SHRINKING OF INFERTILE EGGS.

The changes in external appearance undergone by infertile eggs are sufficiently different from those of normal fertilized ones to merit separate mention. One fact is important. From thousands of infertile eggs laid by moths in the laboratory not a single one ever hatched or showed the slightest external signs of embryonic development. Almost as soon as they are laid infertile eggs acquire a distinctly yellowish color, and within a few hours begin to shrivel up. After twenty-four or thirty-six hours they are always greatly shrunken and are acquiring a dusky color. From the very first they are higher and more conical than the normal eggs, this shape being accentuated by the shrinking, which occurs principally in an equatorial direction.

EATING OF SHELLS AND EGGS BY NEWLY HATCHED LARVÆ.

In the great majority of cases the newly hatched bollworms do not go immediately in search of food, but turn their attention to the deserted eggshell. Not content with the portion already gnawed out in their attempts to escape, they start anew to eat the shell. This may last only for a few minutes, or, again, may continue for nearly an hour. Frequently the entire shell is consumed, although often only one-half or three-fourths of it is eaten. What may be the benefit derived from eating the tough chitinous shell is rather uncertain. The idea that the larva derives any nourishment therefrom, or that it destroys the shell to remove traces of its own presence on the plant, can hardly be accepted. Nevertheless, the eating is a very constant habit.

After this is done the larva begins wandering about in its search for food. Quite often in captivity, when large numbers of eggs are close

together and plant food is scarce, they may develop cannibalistic propensities and begin feeding on adjacent unhatched eggs. Owing to the way the eggs are scattered about in nature, such an occurrence must be rather rare under normal conditions.

PERCENTAGE OF EGGS THAT HATCH.

In all lots of eggs laid by fertile females, the percentage that fail to hatch is so small that it was disregarded except in a few cases where careful counts were made. These show that of 493 eggs 6 did not develop, giving an average of 1.22 per cent, or about 1 in a hundred. This is doubtless the approximately correct percentage for the hatching of eggs laid out of doors.

LENGTH OF THE EGG STAGE.

During the summer of 1904 a long series of observations was made in the laboratory by Mr. A. A. Girault to determine the length of the egg stage at different dates during the entire season and at varying temperatures. In all, the developmental period for over 4,300 eggs was recorded. These results may be tabulated as follows:

TABLE XIV.—*Length of the egg stage at different dates throughout the season at Paris, Tex., 1904.*

Date of hatching.	Length.	Date of hatching.	Length.	Date of hatching.	Length.
	Days.		*Days.*		*Days.*
April 14	8	June 23	$2\frac{7}{8}$	August 31	$2\frac{3}{4}$
April 15	$7\frac{1}{2}$	June 25	3	September 2	$2\frac{1}{2}$
April 21	8	June 26	3	September 12	$2\frac{1}{2}$
April 28	$5\frac{1}{2}$	June 27	$2\frac{2}{3}$	September 25	$3\frac{1}{2}$
May 18	$4\frac{1}{2}$	July 10	$2\frac{2}{3}$	September 30	$3\frac{1}{8}$
May 20	$4\frac{1}{2}$	July 12	$2\frac{1}{4}$	October 9	$4\frac{1}{8}$
May 23	$4\frac{1}{5}$	July 13	$2\frac{1}{2}$	October 12	4
May 29	$3\frac{1}{2}$	July 18	$2\frac{3}{5}$	October 14	$4\frac{1}{8}$
May 30	4	July 19	$2\frac{1}{2}$	December 1	17
June 7	$3\frac{5}{6}$	July 25	$2\frac{3}{8}$		
June 16	3	Aug. 5	3		

A clearer conception of the varying length during the season may be had from the following curve (figure 4), which is based on the data given in the table:

In general it is seen that during the warmer parts of the season the egg period is much shorter than in the spring and fall. Although the embryonic period is thus inversely proportionate to the temperature, it is not so in any constant ratio. A number of calculations regarding the sum of effective temperatures[a] to which different lots of eggs have

[a] Following the theory of Merriam (Nat. Geog. Mag., VI, 229–238, 1894), the sum of mean daily temperatures above 43° to which the eggs had been exposed during development was calculated with the following result: Lot 1, April 14–22, 189°; Lot 2, June 22–25, 111°; July 15–18, 105°; November 1–17, 203°. Assuming 45° to mark the inception of embryonic development, the figures agree somewhat more closely: 173, 105, 100, 169. The summer sums are lower than the spring ones in either case.

been subjected fails to show any very constant ratio between the two. Under normal conditions the longest egg period recorded in the spring was eight days, and in the fall seventeen days.

EFFECT OF REDUCED TEMPERATURES.

Aside from the numerous records of the length of the egg period at different temperatures under normal conditions, a few experiments were made to ascertain the effect of much reduced temperatures on

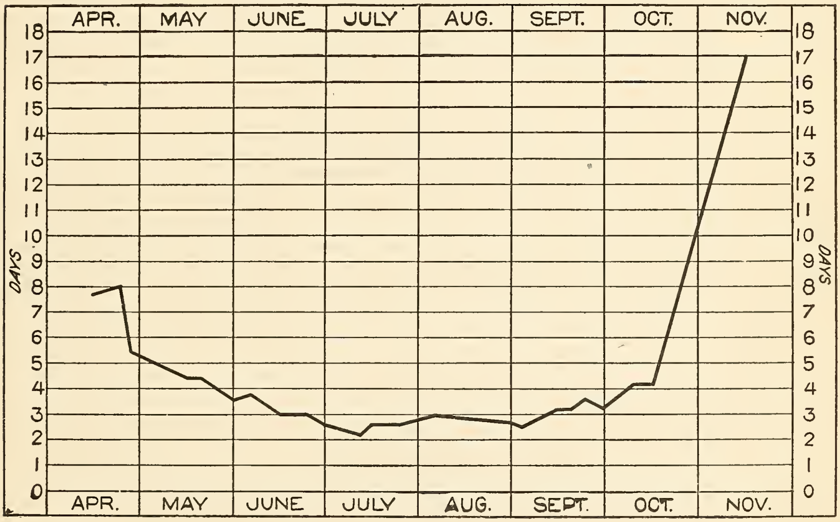


Fig. 4.—Diagram showing relative length of egg stage during season of 1904, Paris, Tex. (original).

embryonic development. The first series consisted of six lots which were placed in an ice-box where the temperature varied irregularly, between 50° and 60° F. The appended table summarizes the results:

Table XV.—*Effect of low temperatures on embryonic development.*

Number of eggs.	Age of egg.	Time in ice-box.	Remarks.
		Days.	
4	Brown ring present ..	13	Eggs showed no development until removed, then hatched after 48 hours.
1	About to hatch	2	Egg showed no development until removed, then hatched after 3 hours.
428	Newly laid	$10\frac{1}{4}$	A very few developed the brownish band, a few shriveled, and the greater portion remained white until removed, when they hatched after $2\frac{1}{4}$ days.
Many.	.....do	10	Were dark at the end of 10 days and hatched on being taken out.
600	.....do	33	Eggs developed a wide brown band and became orange yellow; 12 hours after removal they darkened as if to hatch, but shriveled instead.
382	.....do	13	After 13 days many were hatching, while about 50 were hardly developed.

The effect of much lower temperatures was tested at the Paris ice factory, where the management very kindly placed at our disposal their

cold-storage vaults for these and other experiments. The following temperatures were tried on two lots of eggs, some freshly laid and others partly developed. After the periods mentioned the respective lots of eggs were removed and the percentages hatching noted, as shown in the table:

Table XVI.—*Effect of lower temperatures on eggs.*

Treatment.	First series—eggs with trace of brown ring.	Second series—brown ring well formed.
34° F. for 48 hours	About 90 per cent hatched	Practically all hatched.
34° F. for 24 hours, then 27° F. for 72 hours.	About 50 per cent hatched	Do.
34° F. for 24 hours, then 27° F. for 24 hours, then 18° F. for 72 hours.	About 25 per cent hatched	About 33 per cent hatched.

It is evident from the figures in the table that eggs which are further developed are less susceptible to the effects of cold, and that the eggs are able to withstand short periods of cold better than longer ones. Although there was only about twelve to eighteen hours difference in the age of the eggs in the two series, the proportion hatching from the older one was from 10 to 50 per cent greater. Some of the larvæ hatching from these eggs were kept to see if they had been weakened in any way by the cold, but all seemed as healthy as larvæ hatched under normal conditions. The shock to the egg in the experiments must have greatly exceeded that caused by any sudden cold spell to which they might be subjected in the early spring.

EFFECT OF ATMOSPHERIC CONDITIONS.

Moisture and dryness seem to have no effect on the time required for development. A number of eggs submerged under water shortly after they were laid and others placed in a desiccator dried by sulphuric acid, hatched in practically the same length of time as a check lot under normal conditions. This resistance to atmospheric conditions is no doubt due to the thick, impervious, chitinous eggshell which prevents the transpiration of water vapor to any extent.

EFFECT OF SUBMERGENCE ON EGGS.

In the spring a good proportion of the eggs are deposited on young corn plants; they are often subjected to wetting by heavy rains which occur during this season of the year, and at times are washed down into the "bud" where the rain water accumulates. To ascertain how much submergence under water the eggs are able to withstand, a number of experiments were tried in the laboratory. On June 4, 84 freshly laid eggs were submerged in six lots for periods varying from twenty-five minutes to four hours. Of these only 2 failed to hatch, and these were not in the lot which was under water longest. At another time a card with 35 eggs attached was placed in a vial of

water. The eggs had been laid about eighteen hours and were left under the water for three days. At the end of this time 8, or 23 per cent, had hatched and 3 larvæ remained, drowned in the water, while the other 5 had crawled up into the air and escaped. From this it is evident that the short periods during which eggs are exposed to extreme moisture in nature can have but little influence on them.

EGGS DESTROYED BY STORMS.

A very important factor, however, and one which undoubtedly causes the destruction of immense numbers of eggs, is the mechanical force of the rain during violent storms. Although they are rather firmly attached, the combined effects of rain, wind, and sandy particles washed against the plants removes many eggs. On two occasions during the spring, May 16 and May 29, plants in the laboratory garden known to have had eggs on them were examined after the rains and most of the eggs were found to be missing. Regarding field conditions, no positive data are at hand, but the unusual scarcity of eggs on corn after hard rains was evident on several occasions.

EFFECT OF SUN ON EGGS.

There is an opinion held among many planters that a large number of eggs, when laid on exposed portions of the plant, are destroyed by the rays of the hot midsummer sun. This led us to try the experiment of subjecting eggs to the direct rays of the sun. On August 30 a lot of 20 eggs which had been laid on a dried cotton leaf were pinned high up on a cotton plant, where they were in continuous sunshine during the day. All hatched after the normal period. Again, a few days later a moth was caged over a few leaves of a growing cotton plant, and some 50 eggs were laid on the upper sides of the leaves. After this the cage was removed and the leaves slanted so as to receive the perpendicular rays of the sun. The eggs were in no way injured, however, and practically all of them hatched normally.

THE LARVA.

When the young larva hatches from the egg it is scarcely over a millimeter in length, and during growth it molts or sheds the skin six times before becoming a pupa or chrysalis. Very exceptionally one of these molts may be omitted, the bollworm pupating after only five molts. Each successive instar is larger, and the larva grows more and more rapidly as it nears maturity. The larvæ were carefully studied by Mr. Girault during the course of his breeding work, and the technical descriptions included in the following account have been prepared by him from notes made at that time.

The larva is of the usual noctuid type, resembling in general aspect some of the cutworms, with no peculiar characters which will readily identify it. (See Pl. VI, figs. 1 and 2.) It varies so much in color that considerable study was necessary before a good detailed description could be drawn up. It was found convenient to choose one of the predominating forms as a type and refer other varieties to it. The following is a description of this especially common form:

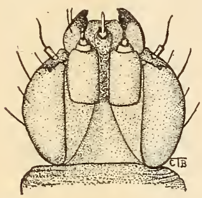


FIG. 5.—Head of bollworm larva—ventral view (original).

Body dark, the ground color pale ocher-yellow; the upper side brownish, marked with nine (or seven) fine interrupted longitudinal lines of yellowish white, including the median line. The latter bordered with broader lines, which are slightly darker than the ground color. The upper side stripes dull orange or brown, as wide as the lower or stigmatal stripes, which are pale yellow and conspicuous. Thoracic segments paler. Head reddish-yellow or brownish, spotted; the cervical shield varying from reddish-yellow to shining black, more or less marked with whitish or with a pale dash along each side. Anal shield obsolete. Body beneath pale, with glaucous median and lateral stripes (absent in the first three stages). Tubercles shining black, i and ii [a] on first and second abdominal segments and i on the eighth abdominal segment more conspicuous, those behind the ninth segment concolorous with the body. Thoracic legs black, prolegs pale.

This color type is very constant in all larvæ through the first two instars, fairly so in stages three and four and in many larvæ until maturity.

During the first three instars a midventral row of orange spots is invariably present, becoming faint in IV [b] and disappearing in V. In the first three instars the anal shield is dusky and complete. In the first instar (and sometimes in the second, in spring and fall) the head is black.

The simplest variations from this type consist in a change in the ground color, in the color of the fine lines on the dorsum, or in that of the lateral stripe. A very slight change in depth of color to rust-red or orange-yellow is common. A change to pinkish or greenish leads to the two other color types next to be considered (Pl. VI, figs. 2 and 3).

These begin to appear in stages IV and V, usually at the time of molting or, more rarely, suddenly during an instar. The first of these is characterized by a greenish ground color and general absence of darker or lighter markings. Occasionally this type shows dark striations and thus passes over somewhat to the brown type. In other specimens rose-colored side spots are developed which serve more or

[a] These numbers refer to the classification of larval tubercles as given by Doctor Dyar.

[b] The Roman numerals refer to the respective stages, thus: I, II, III, IV, V, VI.

less as a transition to the third type, which is pink or rose colored. The dorsal color pattern in a dark type of larva is shown in Plate VI, figure 4.

DESCRIPTIONS OF INSTARS.

Following are the detailed descriptions of the different stages of a generalized larva.[a] No reference is made to the color variations or to slight individual differences shown in the specimen at hand:

Stage I.

At exclusion from the egg the tubercle areas are pale and the cervical shield characteristically crescent-shaped, its posterior margin regularly convex, the anterior margin concave on each side and acutely produced medially. Shortly afterwards both become normal for instar I.

	Millimeters.
Average length at hatching	1.5
Average length before ecdysis	3.8
Average width of head cast	.3

"Semi-looper." Body slender; pale translucent, yellowish in certain lights; greenish after feeding. Surface minutely hairy. Head much larger than the following segments, cordate; shining black, bearing many setæ. Mouth parts, ocellar spots, and antennæ pale. Cervical shield shining black, sometimes paler, bearing eight small tubercles arranged in two rows of four each; shape broad, peltate, the anterior and posterior margins emarginate or sinuate, the sides oblique. Anal shield dilute black, quadrate, emarginate behind; bearing eight small tubercles. Legs dusky, furnished with many stiff setæ. Prolegs pale, their shields quadrate, dilute black, the latter being in reality the blackened area surrounding tubercle vii; the anal pair with an inverted V-shaped dusky marking on the lateral aspect; the two anterior pairs shorter than the others, first one-half as long as third and fourth and the second slightly shorter than the third and fourth. Spiracles inconspicuous, black. Body beneath pale, the ventral nerve ganglia showing through as single round orange spots on segments I to X.

Tubercles minute, situated in large irregularly circular dusky areas which are absent in the larva directly after exclusion from the egg. Tubercles arranged as follows:

Segment I: i–viii placed in two rows of four each above and in front of the spiracle.

Segment II: Ten tubercles in a transverse row across the segment, the line curving forward; i smallest, ii largest, twice the size of the next smaller and equal to v. A single tubercle above and behind the leg.

Segment III: Arrangement the same; i smaller than i of preceding segment and vi farther back.

Segment IV: i, ii, iii, and iv, circular, equal; seen from above i and ii form a trapezoid; i slightly larger than ii; seen from the side iii, iv, and v form a triangle surrounding the spiracle, iv in the stigmatal stripe; vi absent; vii and viii minute, in a transverse row.

Segment V: Arrangement the same; vii and viii in a triangular group on the venter, the first or outer of vii largest.

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[a] Combined from a series of twelve bollworms hatching from eggs laid by the same moth and reared under identical conditions.

Segment VI: Arrangement the same; vii consisting of two, viii normal, at the interior base of the proleg.

Segment VII: Arrangement the same; vii and viii the same.

Segment VIII: Arrangement the same; i and ii equal; vii and viii the same.

Segment IX: Arrangement the same; i and ii equal, smaller; vii and viii the same.

Segment X. Arrangement the same; i smaller than ii; iv farther back and below the spiracle; vii consisting of but a single tubercle, forming with viii a transverse row on the venter.

Segment XI: Arrangement the same; i and ii equal, larger, forming a square when seen from above; vii and viii as in segment X.

Segment XII: Arrangement the same; i and ii forming an inverted trapezoid, iii nearer to ii, iv opposite v of preceding segment; v and vi absent, viii apparently consisting of two contiguous tubercles.

Segment XIII: Eight minute tubercles in two transverse rows of four each on the anal shield, the posterior row following the outline of the margin; vii minute in a triangular group outside of the anal proleg; viii single, at inner base of proleg.

Stage II.

	Millimeters.
Average length after ecdysis	3.85
Average length before ecdysis	6.50
Average width of head cast	.49

Body stout, tapering slightly before and behind, head smaller than the following segments. Head shining, black or paler with mottled markings, bearing scattered setæ. Ocellar spots brownish red. Cervical shield shining black or paler, trapezoidal when seen from in front, bearing eight setæ. Anal shield dark, paler at base and tip. Legs shining black, paler at the joints.

Body marked as follows: Ground color pale greenish, with comparatively broad median and dorso-lateral lines of orange or brown, which are interrupted at the incisions and are less distinct on the thorax. The dorso-laterals branched at the middle of each segment, giving out dorsal and ventral arms. The former forms another interior parallel line and the latter embraces tubercles iii and iv. On the sides of the body irregular paired lines of orange or brown define incompletely a faint creamy stigmatal stripe. Body beneath pale greenish with a median row of orange spots which fade out behind. Anal prolegs marked at the base behind with a looped dusky line. Spiracles larger, black, and resembling the tubercles.

Tubercles shining black or dusky, their setæ black. Arranged as follows:

Segment I: Eight on cervical shield, as in i; two contiguous ones above and in front of the spiracle in an oblong kidney-shaped area; two other contiguous ones in front and below the spiracle; one in the center of their large black area and the other at the edge; also two contiguous tubercles at the base of the leg.

Segment II: Twelve tubercles in a transverse row across the segment, the lower (vi) inconspicuous, its area absent; i and iv equal, one-half as large as iii and v; ii slightly smaller than iii; vii situated behind iv and v, forming with them a triangle; the tubercle above the base of the leg single, equal to iii.

Segment III: Arrangement the same; ii, iii, and iv equal; posterior tubercle a little smaller.

Segment IV: i, ii, and iii equal, iv and v equal and smaller, all in circular areas; i and ii forming a trapezoid when seen from above; iii above the spiracle, iv behind the spiracle, and v below; vi present, in a line with the thoracic leg tubercles; vii and viii in a transverse row of three on the venter, the outer of vii minute or absent and the inner much larger.

Segment V: Arrangement the same; v much farther below the spiracle; vii and viii in a parallelogram on the venter, the outer of vii minute or absent, the inner equal to viii.

Segment VI: Arrangement the same; vii in an inverted triangular group of three exterior to the proleg; viii minute, on venter at inner basal angle of proleg.

Segment VII: Arrangement the same; i and ii slightly smaller.

Segment VIII: Arrangement the same.

Segment IX: Arrangement the same.

Segment X: Arrangement the same; iii irregular; iv below and behind the spiracle; vi smaller; vii and viii in transverse row of two on the venter, vii much larger than viii.

Segment XI: Arrangement the same; i and ii forming a square when seen from above; iii, iv, and v equal, closer to the spiracle; vi smaller, closer to v; vii and viii in a row of two, equal.

Segment XII: Arrangement the same; i, ii, and iii equal and smaller than iv; i and ii forming an inverted trapezoid seen from above and i, ii, and iii forming a triangle seen from the sides; vii and viii in a transverse row of two tubercles, of which vii is the larger.

Segment XIII: Arrangement the same; viii double, situated at inner basal angle of anal prolegs.

STAGE III.

	Millimeters.
Average length after ecdysis	8.96
Average length before ecdysis	10.92
Average width of head cast	.80

Body slightly narrower on the three anterior segments and suddenly sloping behind on the eleventh segment. Ground color pale, translucent, marked as follows on each side of the pale yellowish median line: First, a line of reddish; second, an equal line of yellowish white; third, a broader line of reddish; fourth, a narrower line of yellowish white; fifth, a stripe of reddish; sixth, the pale yellowish stigmatal stripe, more or less interrupted in the center of each segment. Following these below the spiracles is an irregular brownish stripe. Under side of body pale, except for brownish marks descending from above. Orange spots generally visible except posteriorly.

Head reddish yellow or darker, spotted with dusky markings which leave a more or less distinct inverted V-shaped mark on the front. Ocellar spots pale with dark margins, placed in a curved line. Mouth parts pale. Mandibles fine toothed, darker at the tips. Cervical shield dark, or pale with the margins darker; broad, with the front margin straight and the posterior edge concave, sides curved, posterior angles truncate or obtuse; sometimes with paired line of spots near the median line; its disk transversely impressed behind. Anal shield much smaller, dusky, three or four sided, emarginate in front, its disk roughened. Legs black, bearing many stiff setæ. Prolegs pale, their shields shining black, sometimes paler. The anal proleg with an inverted V-shaped marking on its shield. Prolegs about equal in size, first pair slightly larger. Crotchets or claws consisting of at least twelve pieces. In locomotion, larva humps segments I and II of abdomen.

Tubercles nearly the same as in Stage II, much larger and their setæ larger and stiffer. The margins of the tubercular areas quite irregular and the smaller tubercles circularly roughened. On the cervical shield the two middle tubercles of the posterior line are nearer the median line and a little farther forward. On segments I to III, vi is larger and circularly roughened. On segments IV and V, iii is largest, iv and the second of vii each a little smaller and each fully five times larger and somewhat blacker than the others in groups vii and viii. On segment X, ii is closer to the median line, so that i and ii form a square when seen from above.

STAGE IV.

	Millimeters.
Average length after ecdysis	15. 65
Average length before ecdysis	17. 85
Average width of head cast	1. 33

Body slightly narrower behind. Pale translucent, minutely hairy; marked as follows:

Dorsal surface reddish, the median line pale yellowish, as are also three more pale lines on each side of it. Of these the lateral ones are broken behind segment X. The dorso-lateral stripe is a deeper rust-red and the stigmatal stripe which lies immediately below is broad and pale yellow, sometimes tinged with brown above. Below this is a stripe of reddish brown which is waved along the lower margin, embracing tubercle vi, narrowing gradually beyond the sixth abdominal segment and embracing the bases of the thoracic legs anteriorly. Underside of body pale, with indistinct brownish marking on the basal abdominal segments; median line of orange spots sometimes to be seen, as is also a pair of grayish side lines.

Head equal to following segments; brownish yellow or brown, with darker oval spots, and an oblique dash on each epicranial lobe, which forms an inverted V-shaped marking on the front; surface furnished with many pale setæ. Mouth parts darker and gular surfaces pale, the ocellar spots in a strongly curved line. Cervical shield shining, blackish, with a conspicuous pale dash along each side, a faint pale median line and four pale spots which form a square on the disk. Shield broad with obtuse angles, the front margin sometimes notched, the sides and posterior margin sinuate. Anal shield inverted, crescent-shaped, triangular, or four-sided, dusky or concolorous with the body. Legs shining black. Prolegs pale, except anal ones, which are black with whitish markings externally behind, the area of tubercle viii dusky. Prolegs about equal in size, first and second pairs more slender. In locomotion the hump at the base of the abdomen is less noticeable. Spiracles black, inconspicuous, more noticeable before and behind.

Tubercles about the same as in Stage III, but more conspicuous and with black setæ. On segment I the two contiguous pairs are directly above and behind the spiracle, respectively. On segments II and III, tubercles i, ii, and iii gradually increase in size by about one-half, respectively; tubercle iv often as in the next instar; vi adjacent to v on segment II. On segment IV, i and iii are equal and the largest, and ii, iv, and v equal, each about half as large as i; i, ii, iii, and iv are conspicuously conical and the second of viii sometimes marked with paler dots. On segment V, iv is closer to the spiracle, and iii and iv are adjacent, the latter irregular. On segment VI, i and ii are equal and iii is the largest. On segment VII, vi is slightly larger and more depressed; still more so on segment VIII, while on segment IX it becomes very large and quite flat. On segment X it is again much smaller and nearly the size of iv; on this segment iv is below and behind the spiracle almost in a line with v. On segment XI, iv and vi are again equal. On segment XII, i is the largest, and iii one-half smaller. On XIII, the anal segment, vii consists of five tubercles on the outer side of the anal proleg, and viii is the same.

STAGE V.

	Millimeters.
Average length after ecdysis	24. 27
Average length before ecdysis	28. 32
Average width of head cast	2. 03

Body tapering slightly behind; translucent, the ground color ocher-yellow or paler, marked as follows: Median line pale yellowish, bordered on each side by alternating lines of brown and pale yellowish; of the former there are three on each side, and of the latter four, the inner brown line being widest and the outermost pale one

indistinct. All of these lines were broken behind the eleventh segment. Following these markings is the broad darker brown dorso-lateral stripe, which is faintly streaked with pale. Below this is the pale stigmatal stripe which is bordered below and sometimes above with yellow. Subspiracular stripe poorly defined, followed by the gray stripes on the sides of the venter. Venter with a median gray or pale line, the nerve ganglia not to be seen externally. General color of thorax above paler than the abdomen.

Head brown or reddish, marked much as in Stage V, front with an imperfect X-shaped pale marking. Mandibles brown, five-toothed, the two inner teeth minute. Cervical shield brownish yellow, with irregular pale markings and black margins. Shield broad, almost covering the dorsum of the segment, its surface microscopically sculptured into five-sided areas and bearing at the center a shallow transverse impression. Anal shield colored like the body, the sides darker; shape triangular, with sinuate or notched margins. Legs and prolegs pale, the anal prolegs spreading.

Tubercles inconspicuous; i spotted with dusky, ii spotted with shining black; i and ii are the largest on segments IV, V, and XI, where they are conical, shining black and conspicuous; iii and iv shining black, the latter inconspicuous; vii and viii concolorous, their setæ pale. Arrangement differing from that of Stage IV as follows: On segment I, the area of the first pair is oblong and the additional tubercles at the base of the legs are minute. On segments II and III, iv is flat, depressed, and circularly roughened. On the lower side, in front of the base of the legs, are two widely separated pairs of minute tubercles and a third pair at the outer bases of the legs. These tubercles first appear as a single pair in stage III. On segments V, VI, and VII, i, ii, and iii are equal and iv is much smaller, v is below the spiracle and further from it than iii and iv. On the succeeding segments vi increases in size, equaling iii on segment VII, exceeding it on segment VIII, and equaling it on segment IX; afterwards, as in stage IV. On the last segment the two tubercles of viii form an oblique line.

Stage VI.

	Millimeters.
Average length after ecdysis	34.95
Average length when full grown	42.25
Average width of head cast	3.95

Body somewhat stouter than in Stage V, the first and second abdominal segments distinctly widened and the tip of the abdomen narrowed. Ground color opaque yellowish, body marked as follows: Median line pale, interrupted, bordered by a broader stripe of velvety black, which is finely lined with a pale streak. Aside from these the dorsal region is greenish-yellow, marked on each side by fine narrow yellow lines, the inner and outer ones broadest and the others often interrupted. Beyond the eleventh segment all are irregular, and the median black lines are fused together. Dorso-lateral stripe dusky, broad, and conspicuous, indistinctly marked by three fine broken pale lines. It extends from the head to segment XII, where it suddenly fades out. Stigmatal stripe broad and conspicuous, pale yellow, bordered below with whitish. It extends back from the head, gradually tapering to the base of the anal proleg. Below this the surface is irregularly marked with whitish. Under side of body greenish-gray, the middle and side stripes whitish, narrow, and quite conspicuous, except on the thorax and apex of the abdomen. Sides of the body below more or less tinged with pink. Thorax not paler.

Head brownish red, tinged with green, its sculpture and spots irregularly polygonal. Paraclypeus paler, transversely grooved. Clypeus densely grooved. Mandibles dark at tips, with an indistinct sixth tooth. The cheeks paler. Cervical shield brownish red, margined with black behind and along the sides, marked irregularly with white; the edge curved in front and straight or emarginate behind, and the disk with a median and two transverse impressions, its tubercles placed in minute

depressions. Anal shield triangular, irregularly marked with paler, its margins convex. First and second pairs of prolegs one-third shorter than the third and fourth; anal prolegs clasper-like. In locomotion the hump at the base of the abdomen is scarcely noticeable.

Tubercles much as in Stage V; i and ii on segment IV and iii and iv on all segments shining black, the others inconspicuous. On segment I the second pair are separated, the posterior one much smaller, and the pair at the base of the legs are separate and of equal size. The additional ventral tubercles present in stage V are absent. On segments II and III, tubercle iii is three times as large as i and ii; iv is minute and the ventral tubercles are absent. On segments IV to IX, iii is largest, i and ii are equal, and iv is farther forward. On segment IV, vi is closer to vii, and v and vi are equal. On segment V, v is smaller than vi, while iii and vii are equal. In the group, i is smallest, iii a third larger, iv twice as large, and ii four times as large. On segment VI, iii is just above and in front of the spiracle, and v and vi are subequal. On segment IX, iv is smaller and less distinct, v is farther down, near the base of the proleg, and vi is just above the base of the proleg. On segment X, i, ii, v, and vi are equal, iii is smaller and closer to the spiracle, iv is distant from the spiracle, and vii is four times as large as viii. On segment XI, i, ii, and iii are equal, as are also iv, v, and vi; iv is just behind the spiracle, with vi beneath it, and viii far down on the side of the segment. On segment XII, iii is minute and more depressed, directly below i, and iv is in the stigmatal stripe at the posterior edge of the segment. On segment XIII, vii consists of 8 inconspicuous tubercles on the outer side of the anal proleg, viii midway between the base and apex of the proleg on the inner side.

POSSIBLE CAUSES OF COLOR VARIATION.

In connection with the color variation above referred to, Mr. Girault has prepared a table showing the growth and color differentiation of three larvæ which proved to represent the three well-marked color varieties; all hatched from eggs laid by the same female (var. *ochracea*), and were reared during September under similar conditions, on cotton.

TABLE XVII.—*Variation in three larvæ reared under similar conditions.*

Instar.	Dark variety.	Rose variety.	Green variety.
I.	Normal, marked distinctly with deep orange.	Normal, lemon yellow, marked with dull orange.	Normal, yellowish, marked with deep orange.
II.	Dark, marked with dull orange.	Pale, marked with dull orange.	Marked with dull orange.
III.	Like the type, but lighter and greenish.	Olivaceous, marked with dull orange, becoming paler later.	Grayish, marked with dull orange.
IV.	Dark, greenish, marked with dull orange.	Ground color pale ochreous marked with rust red; later with greenish lines above and conspicuous side stripes.	Typical at first, but after 24 hours changed to green with dusky side stripes and whitish stigmatals.
V.	The usual brown type; olivaceous above with olivaceous side stripes and yellow stigmatals. Twenty-four hours later, dorsal region lighter and stripes very conspicuous. Just before ecdysis, larva green.	The usual brown type dorsal region greenish with yellowish lines; side stripes with crimson spots, stigmatals pale, margined. Later with the crimson spots more distinct.	Typical; side stripes brown; later pale green with pale yellow lines above and darker green stripes. Stigmatals pale yellow.
VI.	Grayish; gray above with whitish and yellow lines; dark, the side stripes dark and the stigmatals yellow.	The usual pink type; pink above the pale lines; side stripes broad, velvety black; stigmatals reddish yellow.	The usual green type; body greenish, the stripes darker green and the lines above pale yellow.

Such facts as these show that the various color types may develop among bollworms grown as nearly as possible under similar conditions, and suggest that the matter is entirely an hereditary one. Nevertheless the apparent predominance of certain types on various plants and under different conditions led us to undertake some experiments along this line. Six lots of ten larvæ and one of three were fed on cotton, tobacco buds, tomato buds, Irish potatoes, flowers and buds of cowpeas, corn silk, and the leaves and spikes of *Amarantus spinosus*, respectively, but variations peculiar to each lot did not appear. The experiment was later repeated with twenty larvæ from eggs of a single moth, fed on cotton, tomato, potato, and tobacco, but afforded no further results. Other experiments were tried by rearing larvæ in moist and dry atmosphere, and in light or dark situations, but no evidence was secured. Cold weather influences to some extent the color of the head. Normally this is black in the first stage and pale in the others, but in the spring and fall and in the ice box, the black color persisted through the second stage.

In the field numerous variations, presumably due to environment were noted. Among larvæ feeding on cotton, the pale pink or green type is apt to predominate, except when feeding on the foliage, when bright greens and yellow make their appearance. On corn all three types occur at nearly all times, although green individuals with crimson spots are rather scarce in midsummer. On alfalfa a uniform green type is most common. These dark greens, noticed in specimens feeding on foliage, may be due in great part to the bright-green color of the blood under such conditions.

DURATION OF LARVAL INSTARS.

This question was worked out very thoroughly by Mr. Girault in the laboratory at Paris during the season of 1904. Some thirty lots were reared with this object in view and the molts recorded as accurately as possible down to hours. The number is too large to represent consecutive generations, and the life cycles of the different lots overlap one another more or less. The following table summarizes the entire number:

TABLE XVIII.—*Duration of larval instars.*

No. of lot.	Food.	Period of growth.	Stage I. Days.	Stage I. Hours.	Stage II. Days.	Stage II. Hours.	Stage III. Days.	Stage III. Hours.	Stage IV. Days.	Stage IV. Hours.	Stage V. Days.	Stage V. Hours.	Stage VI. Days.	Stage VI. Hours.	Total. Days.	Total. Hours.	Sums of effective temperatures.
																	°F.
1	Corn stems	Apr. 1–May 9	9	15	7	4	4	12	6	13	5	4	4	12	37	12	810
2	do	Apr. 10–May 9	5	5	5	21	4	3	3	15	3	19	6	20	24	6	440
3	do	Apr. 19–May 16	4	20	6	4	3	10	4	4	8	21	(*a*)	(*a*)	27	11	677
4	Rosebuds	May 15–June 3	10	0	2	22	3	0	1	21	5	7	6	3	29	5	871
5	Corn silk	June 29–July 17	2	18	1	18	2	18	2	20	2	5	5	1	17	8	668
6	do	July 9–July 25	3	0	3	6	2	5	2	2	1	23	3	17	16	17	656
7	do	July 19–Aug. 2	2	18	1	21	2	10	2	9	2	2	2	13	14	3	532
8	Cotton	July 19–Aug. 3	2	17	3	22	1	23	1	19	2	6	2	18	15	9	657
9	do	July 29–Aug. 13	2	8	2	2	1	23	2	2	3	18	4	8	16	13	682
10	do	July 30–Aug. 16	5	0	2	1	2	1	1	22	2	23	2	23	16	22	632
11	Tobacco	Aug. 4–Aug. 19	2	15	2	12	2	4	2	13	2	8	2	17	14	21	547
12	Cotton	Aug. 7–Aug. 22	3	0	2	0	1	9	2	5	2	13	3	14	14	17	566
13	do	Aug. 8–Aug. 24	2	21	4	4	2	2	2	3	(*a*)	(*a*)	4	2	15	18	525
14	do	Aug. 8–Aug. 23	2	19	2	0	1	18	2	16	1	20	4	7	14	10	520
15	Miscellaneous	Aug. 8–Sept. 6	2	20	2	0	3	10	2	21	8	4	7	13	26	10	1,033
16	Cotton	Aug. 20–Sept. 8	2	19	2	17	1	18	2	7	3	2	5	8	17	23	681
17	Amarantus	do	2	3	2	3	1	16	2	5	2	14	8	22	19	17	737
18	Tobacco	Aug. 20–Sept. 9	2	15	2	1	1	14	3	9	3	21	7	3	20	15	802
19	Cowpeas	Aug. 20–Sept. 1	1	15	1	18	2	5	1	16	2	2	2	14	11	22	478
20	Cotton	Aug. 31–Sept. 18	2	7	2	20	3	0	3	15	4	15	5	0	20	23	735
21	Tobacco	Aug. 31–Sept. 16	2	10	2	8	2	17	3	0	3	18	5	12	19	17	656
22	Tomatoes	Aug. 31–Sept. 20	2	19	3	13	3	10	3	15	3	8	4	13	21	6	702
23	Cotton	Aug. 31–Sept. 17	2	16	2	21	2	12	2	6	4	0	4	9	18	16	646
24	do	Sept. 8–Sept. 25	2	19	2	11	2	3	2	15	2	2	4	23	17	0	429
25	do	Sept. 16–Oct. 5	2	12	2	6	2	21	2	22	3	22	4	14	19	1	687
26	do	Sept. 20–Oct. 20	3	10	3	22	3	9	2	9	6	11	9	12	29	1	960
27	Cowpeas	Sept. 28–Oct. 21	2	18	2	16	3	17	2	14	4	10	5	16	21	19	637
28	Cotton	Oct. 13–Dec. 20	4	11	4	12	8	4	8	11	14	21	(*b*)	(*b*)	70	3	......
	Average		3	11	3	1	2	17	2	22	3	23	5	17	21	2	[c]643

[a] Omitted. [b] Not recorded. [c] In this average Nos. 15 and 28 are omitted.

In the last column are given the sums of effective temperature (above 43°) to which the larvæ were subjected. While the range[a] (429°–871°) is great, an average of 617° does not fall far from most of the records.

The following table shows the average length of the different instars for larvæ feeding on corn and cotton:

TABLE XIX.—*Average length of larval instars for larvæ fed on corn and cotton.*

Instar.	Days.	Hours.
I	3	13
II	3	6
III	2	17
IV	3	0
V	3	19
VI	4	11
Total	20	18

GROWTH DURING THE LARVAL INSTARS.

The comparative rate of growth during the respective larval instars is of interest as indicating the periods of most vigorous feeding, and,

[a] Only rearings on corn and cotton are here considered.

consequently, the periods during which greatest injury is done. Determinations of this character were made in connection with the previously mentioned breeding work.

Measurements made of the length of the body are of but little use, since they may be varied so much by the movements of the larva. There is a rather constant and gradual increase, however, from birth to maturity, as shown by the measurements given below, which are averages of twenty-five larvæ.

TABLE XX.—*Showing amount of growth during, and length at end of, each instar.*

Instar.	Amount of growth during each instar.	Length at end of each instar.
	mm.	*mm.*
I	2.02	3.52
II	2.65	6.17
III	4.53	10.70
IV	7.68	18.58
V	10.51	29.39
VI	13.35	42.74

Thus it will be noticed that a larva shows a greater amount of growth during each succeeding larval instar. This is shown graphically in the accompanying curve (fig. 6).

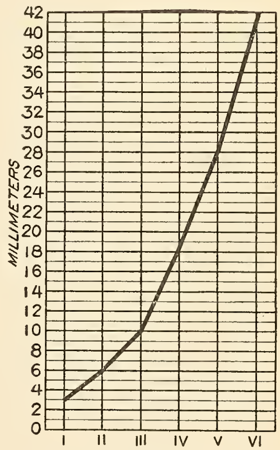

FIG. 6.—Diagrammatic representation of comparative rate of growth of larvæ during different instars (original).

More accurate measurements are those based upon the size of the head, which does not change between the molts, and thus serves by its almost constant size to identify the instar of any given larva. By measuring large numbers of head casts thrown off at the molts, it was found that they are fairly constant for each instar, sufficiently so to enable one to tell the stage of any larva positively. The following table is compiled from measurements of over one hundred specimens:

TABLE XXI.—*Showing average width of head casts for respective larval instars.*

Width and range.	Stage I.	Stage II.	Stage III.	Stage IV.	Stage V.	Stage VI.
	mm.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
Width	0.30	0.48	0.78	1.33	2.05	3.95
Range	(*a*)	0.42–0.54	0.67–1.00	1.21–1.50	1.73–2.28	2.85–5.00

a Practically constant.

It will be noticed that not in a single case do any measurements of the different stages overlap. In abnormal individuals, or in rare cases where the larva undergoes only four molts before it pupates, the measurements are of course irregular and are here disregarded.

The variation in head width, in Stages III and IV, in a lot of five larvæ reared from eggs of a single moth and on the same food, is shown graphically in figure 7.

INFLUENCE OF EXTERNAL CONDITIONS ON GROWTH.

The effect of seasonal variation in temperature on the development of the bollworm is easily noted by glancing down the right-hand column of figures in Table XVIII, page 64. The length of the larval stage is thus seen to decrease from 37½ days, recorded in April, to 14 days during the warmer parts of the summer, and to increase again in the fall.

Experiments were tried to ascertain if atmospheric conditions had any effect on growth, but they gave only negative results. The effect of different diet on growth has been watched, but there seems to be but little relation between the two, except possibly in one case, where it was found that larvæ grew much faster on green cowpea pods than on either corn or cotton.

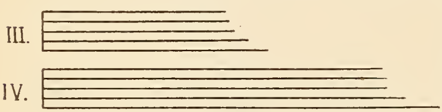

Fig. 7.—Diagram illustrating relative width and variation in width of the head casts of larvæ in third and fourth instars (original).

The effect of temperature on growth was also investigated by rearing larvæ simultaneously at three different temperatures. This was done by means of a commercial chicken-egg incubator, which could be kept at a temperature of from 80° to 90° F.; an ordinary ice box, maintaining a temperature of from 50° to 60° F., and the laboratory breeding room, which was subject to the usual daily fluctuations in temperature.

During the latter half of April a lot of larvæ reared in the incubator at an average temperature of about 85° attained full growth in fourteen days, and the moth emerged twelve days later, making in all twenty-eight days, as compared with forty-five days required in the laboratory, where the average temperature was about 71°. In the ice box, where the temperature was below 60° most of the time, it proved difficult to raise any larvæ beyond the third molt. The following table gives a comparison of the three lots:

TABLE XXII.—*Rate of growth of larvæ at different temperatures.*

Location.	Average temperature.	Larval stage.	Sums of effective temperatures.
	° *F.*	*Days.*	° *F.*
Incubator	85.4	14	425
Laboratory	71	2.8	677
Ice box	57	[a] 41	[a] 516

[a] Three molts.

The effect of severe cold on larvæ was also tried in a number of cases. All subjected to temperatures somewhat below freezing were killed outright by an exposure of from twenty-four to forty-eight hours, but of those kept at 34° F. for forty-eight hours a small percentage survived and matured successfully.

The ability to live for any length of time without food is not very great. Newly hatched larvæ live about twenty-four hours in the laboratory, but it is probable that in nature the drying effect of the sun and other untoward conditions would shorten this period considerably. Larger larvæ usually live several days, and occasionally three-fourths or nearly grown ones will pupate successfully if deprived of food.

NUMBER OF MOLTS.

The number of molts has already been stated. Of 100 larvæ reared in the laboratory at Paris, Tex., in 1904, 90 per cent molted 5 times, 8 per cent 4 times, and 2 per cent 6 and 7 times, respectively.

The cause of this variation in the number of molts in regard to the 10 per cent thus varying could always be traced to abnormal conditions. Highly nutritious food and excessive care in breeding apparently caused less than the normal number of molts. Seven out of eight larvæ reared on cowpeas molted thus. Molts in excess of the normal were caused by neglect and insufficient or disagreeable food.

PROCESS OF MOLTING.

The process of molting is normal. A fews hours after ecdysis the larva stops feeding and remains in an extended, slightly arched position. In this condition it is very helpless, especially when nearly full grown. At the time of molting the body contracts spasmodically, the skin splits back of the head, and the head is thrust out. Three or four minutes more pass before the larva has shed the skin entirely, and after three or four hours feeding begins again.

In midsummer the stages preparatory to molting are very short (15 to 18 hours), and in the fall longer (3 to 4 days). After the earlier molts the larvæ sometimes devour their own shed skins, as do also the older ones, but more rarely.

HABITS OF NEWLY HATCHED LARVÆ ON COTTON.

The feeding habits of the newly hatched larvæ have a very important bearing on the question of poisoning and have for this reason been rather carefully studied. The habit of eating the deserted eggshell has already been described. After this follows a period of very precarious existence for the young larvæ. They begin to wander about in search of suitable food, here and there rasping the epidermis of the leaf or involucre where they happen to be, and passing on to repeat the process. They are not satisfied to remain on the leaves, and very often reach some tender growing tip soon after hatching. This is usually to their liking, and they remain and feed for some time upon the tender foliage. They do not stay long, however, and are soon again on the move after a short interval. If a square is next found they at once crawl beneath the involucre and begin feeding. Otherwise they may feed to a slight extent on a leaf, or another growing tip, until a square is finally found.

During the search for proper food many of the larvæ perish; in fact the great majority of them do. A number of times during the summer from 100 to 150 eggs or newly hatched larvæ placed on a cotton plant have yielded only four or five larvæ after a few days. This is much in excess of the number of eggs usually laid on a plant, and serves to show what an enormous number of the larvæ die in the presence of food in plenty.

One thing which is important and should be borne in mind is that the larvæ almost always feed to some extent on large leaves or tender foliage before they begin feeding inside the squares. If they are to be poisoned it must be largely during this period of external feeding.

EFFECT OF EXTERNAL CONDITIONS ON NEWLY HATCHED LARVÆ.

The young larvæ feeding on corn early in the spring are often washed down by rain and submerged for considerable periods. To test their ability to withstand such conditions a number were experimented upon in the laboratory. Twenty newly hatched larvæ were entangled in a bit of cotton and submerged for seventeen hours. All but four survived the immersion. Larger larvæ can not stand such long periods, but when dropped into water make feeble attempts to escape, becoming stupefied after a few minutes.

CHARACTER OF INJURY.

The characteristic habits of the larger bollworms, like those of the newly hatched larvæ, are utterly different on corn and cotton and must be considered separately.

CHARACTER OF INJURY TO CORN.

In young corn still in the bud the larvæ seek out the tender uncurling leaves near the base of the opening portion (see Pl. VII, fig. 1). Here they bore through the curled mass, making burrows which show as transverse rows of holes after the leaf has fully opened. Occasionally the plant grows too quickly for the bollworm and the separation of layers by unequal growth may squeeze it to death. As soon as the tassels are beginning to form, and while they are still well surrounded by leaves, they are attacked (see Pl. VII, fig. 2). The larvæ now feed on the tassel proper, scarcely ever eating into the leaves or stem. As soon as the ears begin to form the remainder of the plant is no longer disturbed. The damage to corn ears will be considered at greater length elsewhere.

CHARACTER OF INJURY TO COTTON.

The method of attack on cotton before the squares have formed is of little importance, since it is very rare for such cotton to be injured by the bollworm. It is interesting, however, as it shows that the spring generation can feed on cotton if forced to do so. Under such conditions they seem to prefer, when small, to bore into the cotyledon leaves or buds, and later to feed promiscuously on any part of the leaves.

The squares are without doubt the part of the plant preferred by the majority of the larvæ. After the newly hatched larvæ have gained enough strength to get about readily they almost invariably enter a square and begin feeding on it near the base. As a rule the first square attacked is eaten hardly at all, and only a small black puncture is to be seen when the square "flares" some twenty-four hours later. The flaring of a square is a very characteristic process, the bracts of the involucre folding back and exposing the inner portion (Pl. IX, figs. 3 and 4). Almost invariably squares which have flared drop from the plant some hours later, breaking off at the juncture of the petiole and stem. Very rarely they may dry up and remain upon the plant. A very slight injury made by a newly hatched bollworm will cause a square to flare, but they can often withstand a considerable needle prick without harmful effects. The second square to be attacked by the growing larva shows a larger scar and generally a trace of excrement and a few silken threads spun by the larva, which has left it before the flaring begins. Such injury to squares is quite generally known as the work of "sharpshooters;" improperly so, however, since the real sharpshooter belongs to another order of insects.

After the larva has fed upon two or three squares it may either turn its attention to bolls or continue its depredations on other squares or flowers. It has now increased considerably in size and is about one-third grown. If it continues to feed on squares a large hole is

gnawed in one side near the base and the contents eaten out, leaving only a hollow shell still retaining its original shape (see Pl. IX, fig. 4). Subsequent injury to squares is done in the same way, except that the hole eaten by the full-grown larva is considerably larger. Bolls are scarcely ever attacked by newly hatched larvæ, although the latter can subsist on them without difficulty in the absence of other food. Larvæ one-third grown or larger may bore into the bolls at a point not far from the base or farther up on the side, as shown in figures 1 and 2, Plate X. If the boll is small, like the one shown on Plate IX, figure 5, the entire contents are appropriated, as in the case of a square, but if it is large usually only one or two "locks" are badly eaten (see Pl. X, figs. 3 and 4). When the larva leaves the boll its exit is most generally made through the entrance hole, although a second opening is sometimes made. The excrement left in the boll by the departing larva usually stains what fiber may be left in that lock to a dark brown, and often favors fermentation and the development of mold, which quite often ruins the boll entirely. If two or three locks have been destroyed the boll may open more or less imperfectly, as shown on Plate X, figure 4, or fail to open at all. In such bolls the large hole made by the bollworm is always plainly to be seen.

The flowers are often attacked soon after they have opened and before the petals have become pinkish. Usually the pistil, stamens, and ovary are destroyed and the flower ruined (see Pl. IX, fig. 2). The stamens especially seem to be very well liked and injury may be confined to the destruction of these (see Pl. IX, fig. 1).

The leaves of the cotton plant are not fed upon by the bollworm unless squares and bolls are very scarce. Under such conditions they take very readily to leaves, eating them in a way similar to the cotton worm (*Alabama* [*Aletia*] *argillacea*). In the large field cage in the laboratory garden at Paris a method of feeding not noticed elsewhere was observed. The squares and bolls had practically all been destroyed and the large larvæ, boring through the axillary buds into the stem, caused it to break at that point and wither and die.

CHARACTER OF INJURY TO OTHER PLANTS.

The feeding habits of the bollworm on other plants than corn and cotton are rather beyond the scope of the present bulletin and can only be briefly referred to.

On tomatoes the green fruit is usually the part chosen, the young larva boring through the skin at almost any place, while the older ones prefer to enter near the insertion of the stem (see Pl. XI, fig. 2).

Tobacco is injured at the growing tips or "bud" early in the season (see Pl. XI, fig. 1), but later, if the plants are not topped, the green seed pods are preferred.

Injury to ripe peaches still attached to the trees is recorded by Webster[a] in Ohio. Bollworms attack peaches about as they do tomatoes (see Pl. XI, fig. 3).

Peas, beans, and okra are all bored into and the green seeds eaten, the bollworms often being very destructive to these plants (see Pl. XI, figs. 4 and 5).

From eggs laid on rosebuds early in the spring a lot of larvæ feeding upon the unopened buds were reared.

CHOICE OF FOOD BY LARVÆ

Aside from field observations, a series of experiments were made in the laboratory to determine the choice of food by larvæ when plentifully supplied with several kinds. When given corn, cotton squares, green tomatoes, and tobacco buds, the corn is almost always chosen, often after first tasting the others; but with different parts of the corn plant selection is not always so uniform. Apparently the tender bud and ear are about equally attractive. In the case of cotton the flowers and squares were liked best, as is shown in the appended table.

TABLE XXIII.—*Choice of different parts of King cotton by bollworms.*

Part of plant.	Number of larvæ.																	Remarks.
	First series.							Second series.								Total.		
	First day.	Second day.	Third day.	Fourth day.	Fifth day.	Sixth day.	Seventh day.	First day.	Second day.	Third day.	Fourth day.	Fifth day.	Sixth day.	Seventh day.	Eighth day.	First series.	Second series.	
Leaves	2	3	2	1	0	0	0	1	0	0	0	1	0	0	0	8	2	Fifth choice.
Tender growth	2	2	1	4	2	0	0	1	4	2	0	1	0	0	0	11	8	Fourth choice.
Flowers	(a)	(a)	(a)	(a)	(a)	(a)	(a)	4	6	2	4	3	3	4	3	(a)	29	First choice.
Squares	4	3	3	3	5	5	2	2	0	1	4	2	2	2	1	25	14	Second choice.
Bolls	1	1	3	0	0	2	4	0	0	0	2	3	2	1	3	11	11	Third choice.

[a] Absent.

The experiments from which these data were obtained were made by placing leaves, squares, etc., together under a large bell jar with the larvæ. Then every day an examination was made and the part chosen by each larva recorded. No doubt if the experiments had been tried in the open sunlight, the exposed tender growth would not have been chosen so frequently.

RELATIVE ATTRACTIVENESS OF UPLAND AND EGYPTIAN COTTONS.

It was noticed quite frequently that Egyptian cotton was more or less free from attack by the bollworm, while Upland cotton growing adjacent was badly infested. To get accurate data on this point a

[a] Bul. No. 8, n. s., Div. Ent., U. S. Dept. Agr., p. 41.

number of larvæ were supplied with both kinds in the laboratory and their selection noted. The following table gives the preferences of a lot of ten young larvæ on succeeding days:

TABLE XXIV.—*Relative attractiveness of King and Mit Afifi cottons.*

Kind of cotton.	First day.	Second day.	Third day.	Fourth day.	Fifth day.	Sixth day.	Seventh day.	Eighth day.	Total.
King	7	9	8	5	7	8	6	6	56
Egyptian (Mit Afifi)	2	1	2	4	3	2	3	3	20

COMPARATIVE INJURY TO EARLY AND LATE COTTON.

Planters have been taught by the accumulated experiences of many years that early-planted cotton is much less subject to the ravages of the bollworm than cotton planted late. This fact has also been noted by many observers, not only with reference to the bollworm, but to other cotton insects. Thus Riley, as early as 1885, says:

> Our knowledge of the natural history of Aletia [*Alabama argillacea*] and the yearly occurring experiences with its ravages teach us that the principal and most effective means of prevention is to hasten the maturity of the plant so that a portion of the crop shall be beyond the reach of harm from the more destructive July and August broods of the worm.
>
> Improving the cotton seed in the direction just mentioned can be accomplished principally by careful selection of early varieties of cotton or by introducing seeds from more northern regions. Early planting is to be strongly urged in this connection, although, of course, it has its drawbacks in the risks of exceptionally late falls.[a]

Professor Mally, in discussing certain statistics of the relative injury of bollworms to early and late cotton in Texas in 1892, says:

> The late cotton, therefore, shows a loss of 50.6 per cent, while the early cotton shows no real loss. This may be taken as an extreme case, but the general principle remains that late cotton receives by far the greater portion of bollworm attack, virtually protecting the cotton fields about it.[b]

The decided preference of bollworms for squares and young bolls, as compared with mature and more hardened bolls, is shown in the following table, as is also the comparative injury to early and late planted cotton.

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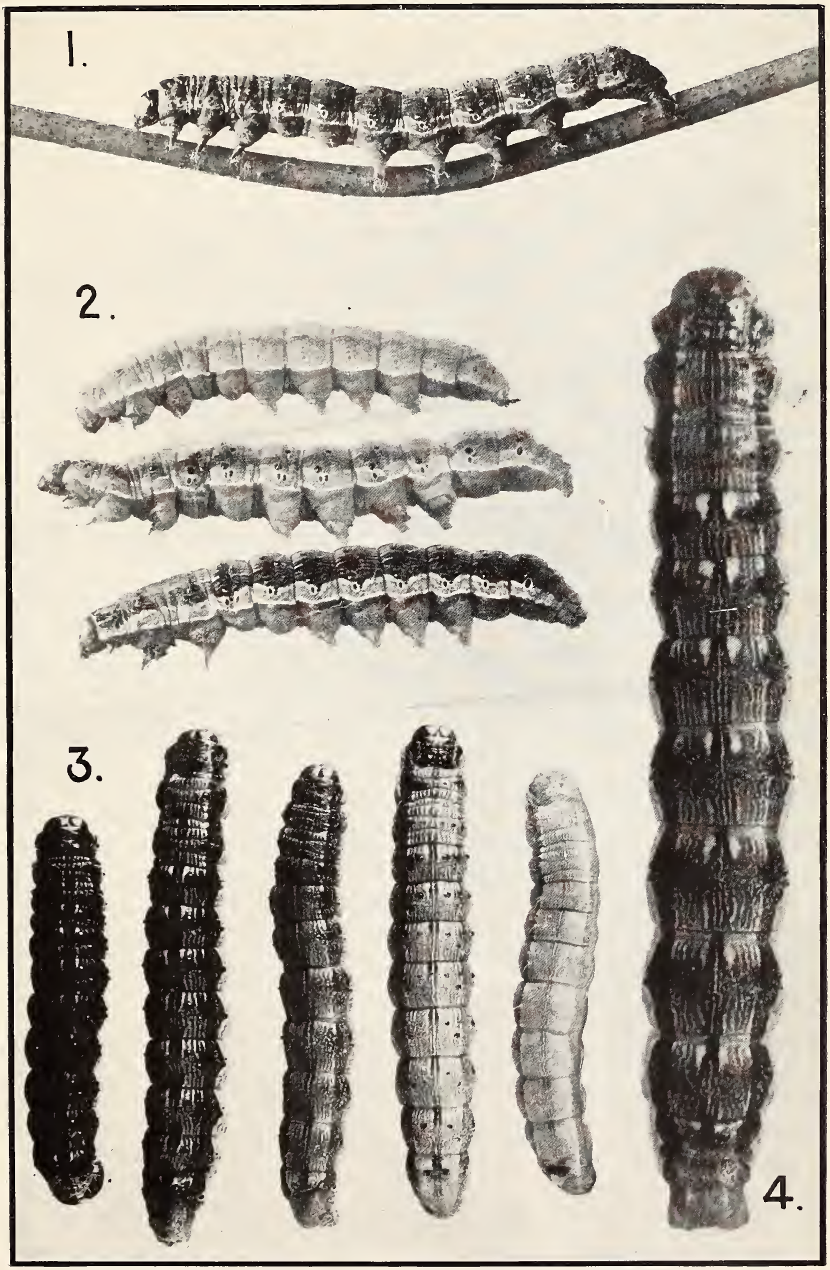
[a] Riley, Fourth Rept. U. S. Ent. Com., p. 120.

[b] Mally, Rept. on the Bollworm, 1902, p. 12, Austin, Tex.

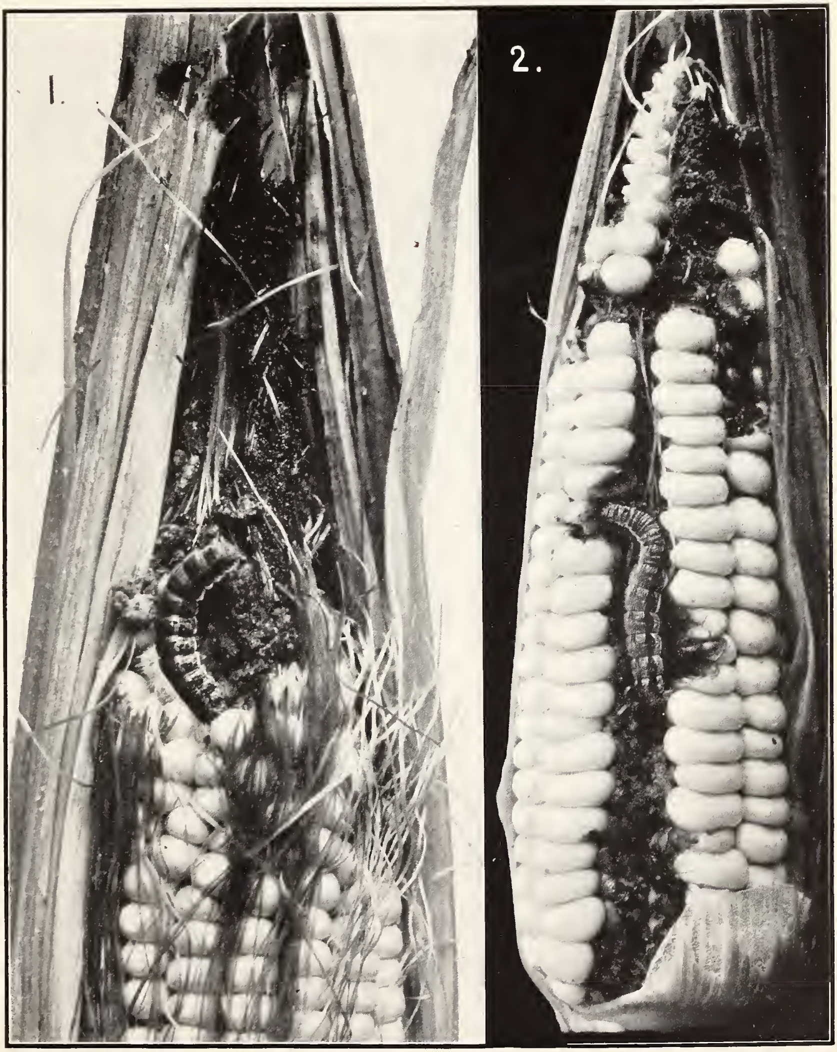


VARIATION IN COLOR AND MARKINGS IN THE BOLLWORM.

Fig. 1, Dark-colored bollworm resting on leaf of cotton plant; fig. 2, three larvæ, seen from the side, showing color types—upper larva, green; middle, rose; and lower, dark-brown colored; fig. 3, five larvæ, showing color variation, seen from above; fig. 4, dorsal pattern of markings of dark-brown colored larva—figs. 1-3 enlarged twice; fig. 4 four times (original).

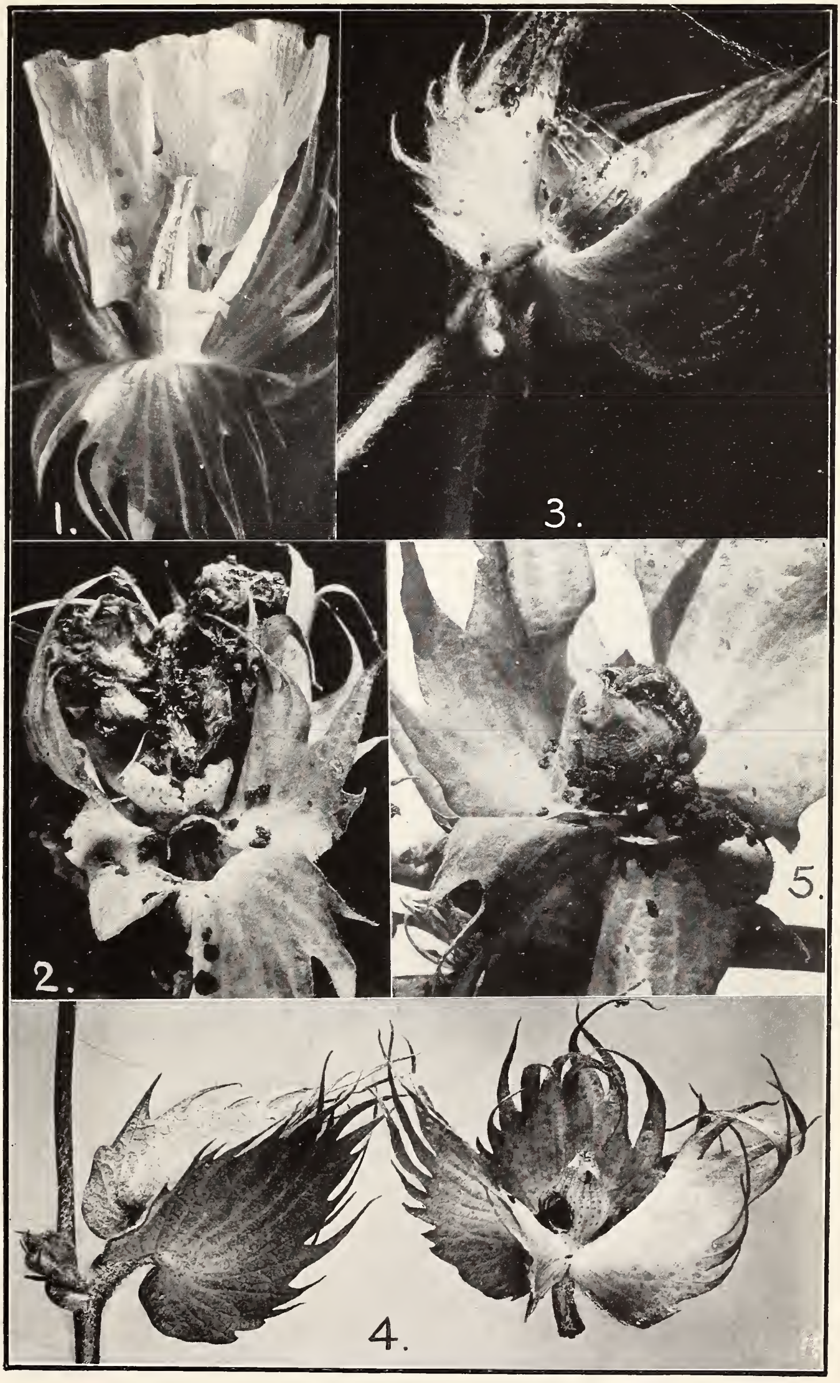
BOLLWORM INJURY TO BUD AND TASSEL OF CORN.

Fig. 1, Portion of young plant, showing injury to "bud" by bollworm; fig. 2, bollworm and its work in corn tassel—both figures reduced about one-third (original).



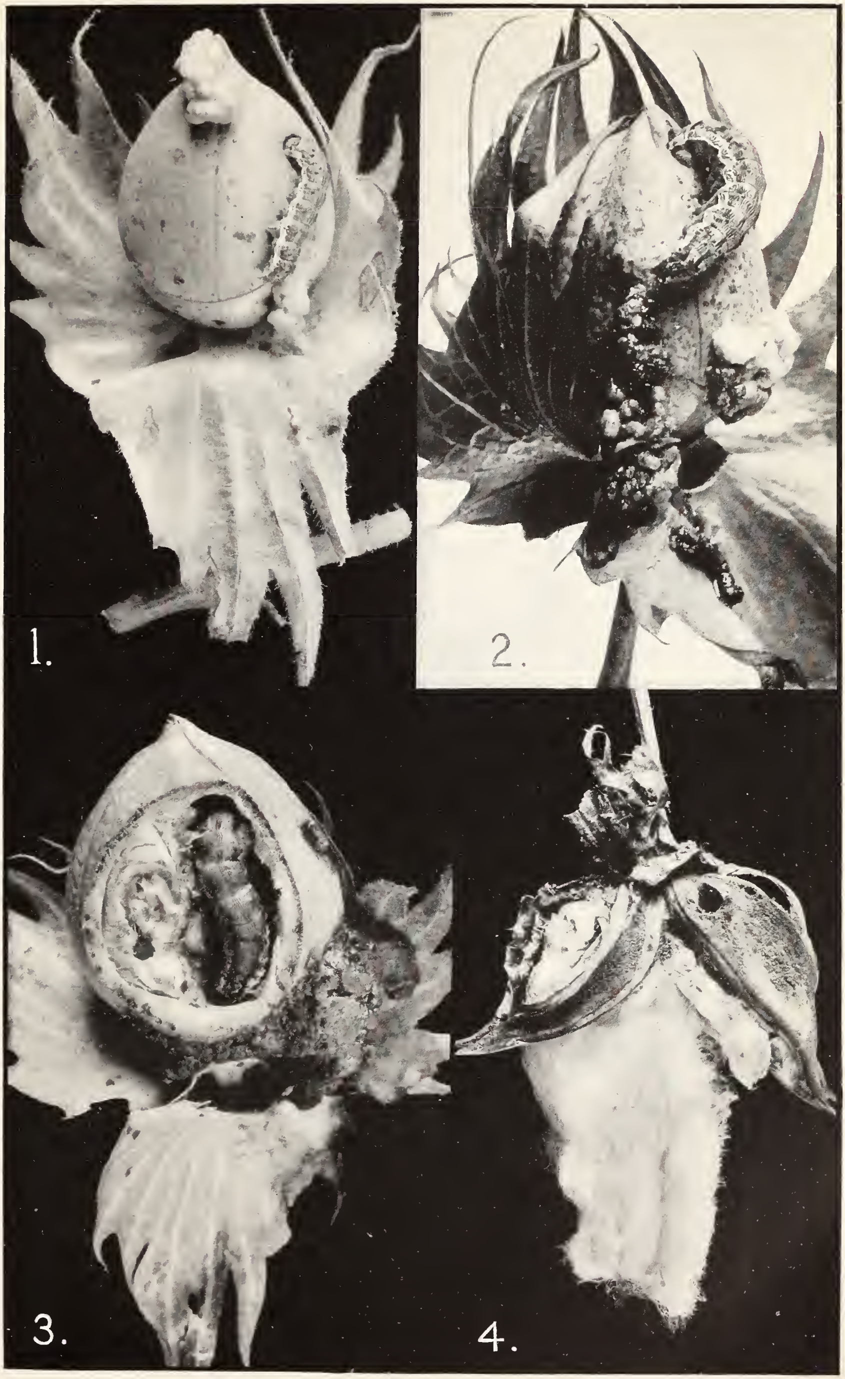
BOLLWORM INJURY TO EARS OF FIELD AND SWEET CORN.

Fig. 1, Bollworm and its injury to ear of field corn; fig. 2, bollworm and its injury to sweet corn (original).



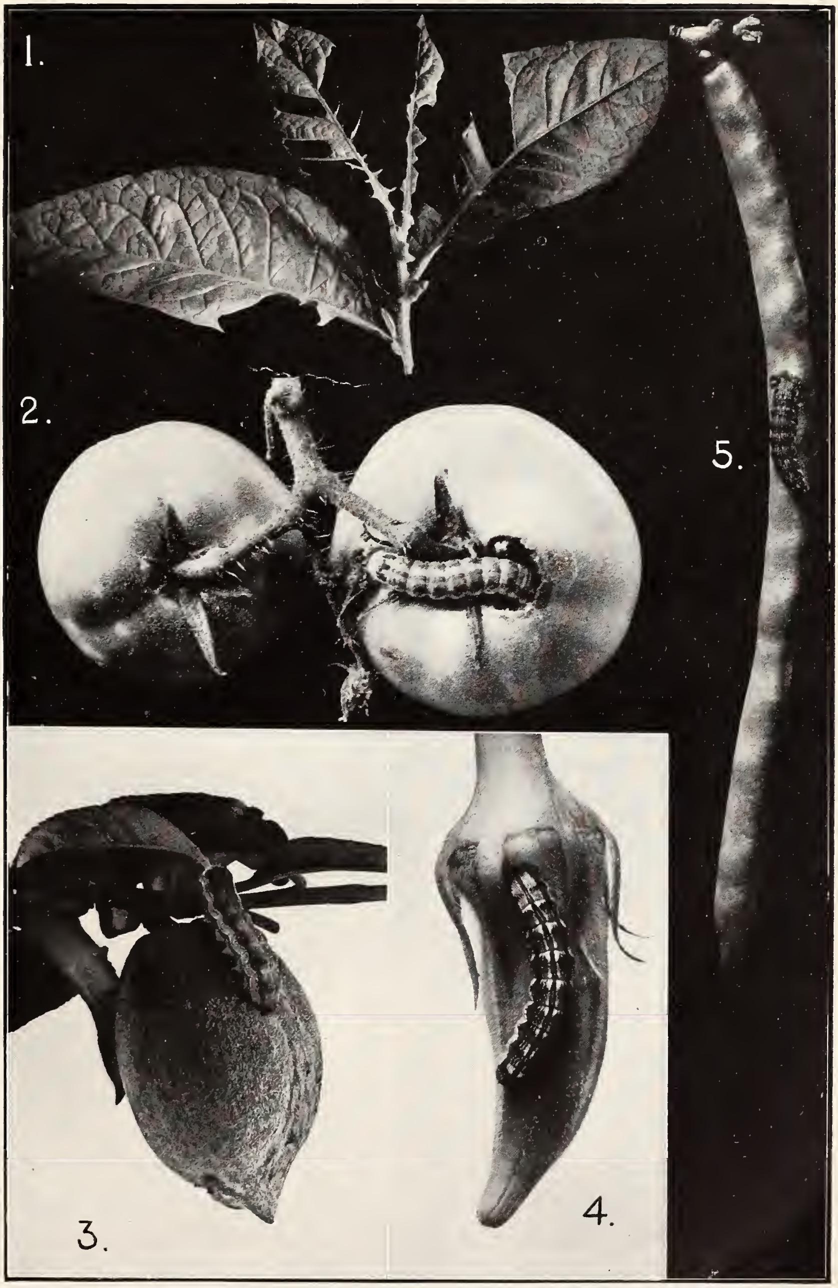
BOLLWORM INJURY TO FLOWERS, SQUARES, AND YOUNG BOLL OF COTTON.

Fig. 1, Bollworm and its injury to cotton flower, stamens already destroyed, natural size; fig. 2, cotton flower destroyed by bollworm, natural size; fig. 3, flared cotton square, showing injury by very young larva, commonly designated "sharpshooter" work; fig. 4, showing, on the right, flared cotton square due to bollworm injury; on the left, normal square, natural size; fig. 5, bollworm destroying young cotton boll, one-half enlarged (original).



WORK OF BOLLWORM IN COTTON BOLLS.

Fig. 1, Bollworm eating into a half-grown cotton boll, twice natural size; fig. 2, bollworm boring into a full-sized cotton boll, slightly enlarged; fig. 3, full-grown bollworm and its work in large cotton boll, somewhat enlarged; fig. 4, cotton boll only partially destroyed by bollworm, two "locks" open, the others destroyed, natural size (original).



BOLLWORM INJURY TO FOOD PLANTS OTHER THAN CORN AND COTTON.

Fig. 1, Growing tip of tobacco plant injured by bollworm, reduced one-half; fig. 2, bollworm and its injury to green tomato fruit, natural size; fig. 3, bollworm boring into green peach, natural size; fig. 4, okra pod attacked by bollworm, natural size; fig. 5, bollworm boring into cowpea pod, two-thirds natural size (original).

Table XXV.—*Showing bollworm injury to early-planted and late-planted cotton.*

BOLLWORM INJURY TO EARLY-PLANTED COTTON.

Date of observation.	Locality.	Number of plants examined.	Total injured.							Total uninjured.							Total fruit on plant.	Average per cent of injury.	Date of planting.	Variety of seed and kind of soil.
			Squares.	Very small bolls.	One-fourth-grown bolls.	One-half-grown bolls.	Three-fourths-grown bolls.	Full-grown bolls.	Total.	Squares.	Very small bolls.	One-fourth-grown bolls.	One-half-grown bolls.	Three-fourths-grown bolls.	Full-grown bolls.	Total.				
Aug. 9	Ladonia	10	31	56	27	17	2	5	138	65	131	106	53	32	59	446	584	23.6	Apr. 1	King. Black-waxy, wooded.
Aug. 11	Ben Franklin	10	13	16	2	4	0	0	35	303	79	88	51	40	23	584	619	5.6	Mar. 29	Hall. Black-waxy, wooded.
Aug. 12	Quinlan	10	0	5	3	1	2	4	15	9	65	2	3	13	165	257	272	5.5	Apr 1	King. Post-oak.
Aug. 15	Willspoint	20	15	39	9	0	0	0	63	165	340	141	86	82	397	1,211	1,274	4.9	....do...	King. Gray, prairie.
Aug. 22	Paris	5	3	22	9	10	1	0	45	11	43	13	16	21	79	183	228	19.7	Mar. 30	Big Boll. Black, prairie.
Aug. 31	Almont	10	4	27	8	3	3	0	45	57	123	26	64	153	330	753	798	5.6	Mar. 23	King. Red River bottom.
	Total	65	66	165	58	35	8	9	341	610	781	376	273	341	1,053	3,434	3,775	......		
	Average per cent of injury	......	9.7	19.5	13.3	11.3	2.3	.8	......	......	......	......	......	......	......	......	......	......		

INJURY TO LATE-PLANTED COTTON.

Date of observation.	Locality.	Number of plants examined.	Total injured.							Total uninjured.							Total fruit on plant.	Average per cent of injury.	Date of planting.	Variety of seed and kind of soil.
			Squares.	Very small bolls.	One-fourth-grown bolls.	One-half-grown bolls.	Three-fourths-grown bolls.	Full-grown bolls.	Total.	Squares.	Very small bolls.	One-fourth-grown bolls.	One-half-grown bolls.	Three-fourths-grown bolls.	Full-grown bolls.	Total.				
Aug. 9	Ladonia	10	75	76	43	20	2	0	216	221	41	73	52	7	1	395	611	35.3	May 2	King. Black-waxy, wooded.
Aug. 11	Ben Franklin	10	56	55	14	5	1	1	132	221	71	60	32	29	17	430	562	23.5	Apr. 15	Hall. Black-waxy, wooded.
Aug. 12	Quinlan	10	4	29	8	10	4	0	55	88	186	45	74	53	46	492	547	10.0	Apr. 25	Big Boll. Post-oak.
Aug. 15	Willspoint	20	18	54	21	8	6	1	108	291	259	82	70	81	186	969	1,077	10.0	May 2	Rowden. Gray, prairie.
Aug. 22	Paris	5	56	67	13	11	7	3	157	210	53	20	34	50	10	377	534	29.6	May 1	Peterkin. Black, prairie.
Aug. 31	Almont	10	149	81	28	8	1	0	267	602	137	62	38	36	31	906	1,173	23.6	June 2	Fleming. Red River bottom.
	Total	65	358	362	127	62	21	5	935	1,633	747	342	300	256	291	3,569	4,504	......		
	Average per cent of injury	......	17.9	32.6	29.7	15.9	6.7	1.7	......	......	......	......	......	......	......	......	......	......		

Table XXVI.—*Comparative injury by bollworm to early-planted and late-planted cotton.*

Locality.	Early-planted. Date of planting.	Early-planted. Seed used.	Per cent of injury.	Late-planted. Date of planting.	Late-planted. Seed used.	Per cent of injury.	Per cent in favor of early planting.	Kind of soil.
Ladonia, Tex	Apr. 1	King	23.6	May 2	King	35.3	11.7	Black-waxy, wooded.
Ben Franklin, Tex.	Mar. 19	Hall	5.6	Apr. 15	Hall	23.5	17.9	Do.
Quinlan, Tex	Apr. 1	King	5.5	Apr. 25	Gin	10.0	4.5	Post-oak.
Willspoint, Tex	Mar. 30	do	4.9	May 2	Rowden	10.0	4.1	Gray prairie.
Paris, Tex	do	Gin	19.7	May 1	Gin	29.6	9.9	Black prairie.
Almont, Tex	Mar. 23	King	5.6	June 2	Fleming	23.6	18.0	Red River bottom.
Average of all observations.			9.3			20.7	11.4	

It will be noted that in determining the percentage of injury observations were made on early and late cotton in the same locality and on the same date, as shown in Tables XXV and XXVI, so that the comparisons are quite fair. The average total injury to early cotton was 9.3 per cent, as compared with an average total of 20.7 per cent to late cotton. This difference is undoubtedly less than would be the case during seasons of more severe bollworm injury than occurred in 1904. The decided preference of the bollworm for squares and young bolls is shown in the figures of average percentages of injury given in both tables. Thus, the sum of the percentages of injury, as shown in the tables, to squares and bolls one-half grown or less is 149.9, while on bolls from three-fourths to full grown the injury amounts to only 11.5 per cent.

The fact of the comparatively less injury to early cotton indicates the desirability not only of planting as early in the spring as possible, but of adopting all other practicable measures that will further the production of an early crop, such as the use of seed of early fruiting varieties, the use of fertilizers to hasten and increase the production of fruit, and early and thorough cultivation. This subject will be more fully discussed under the consideration of remedial measures.

AMOUNT OF DAMAGE DONE BY A SINGLE LARVA.

Owing to the very different method of attack on corn and cotton, the damage done by a single larva is of an entirely different nature in the two cases and will be considered separately.

DAMAGE TO YOUNG CORN.

When the larva feeds on young corn by eating into the bud, considerable injury is done to the unfolding leaves and the plant presents a very ragged appearance. (See Pl. VII, fig. 1.) From general observation it would seem that the small percentage of plants which are injured when young must be less productive later in the season.

Such is apparently not the case, however, as two experiments made on corn plants show. Two average young plants of field corn growing in the laboratory garden were chosen and watched until maturity, with the result shown below:

TABLE XXVII.—*Effect of bollworm injury to young corn.*

Experiment 1.		Experiment 2.	
Date.	Observation.	Date.	Observation.
May 14	Placed a one-fourth grown larva in bud of corn plant $2\frac{1}{2}$ feet high.	May 17	Placed three larvæ (one-fourth, one-fourth, and one-half grown) on corn plant.
May 15	Larva has eaten from one of the partially uncurled leaves in the bud; damage slight.	May 18	Some damage down in bud is noticeable
May 19	Bud is now badly damaged.	May 19	Much injury is now noticeable.
May 20	Damage is greater, but growth is not impaired.	May 20	Damage increased; one larva visible in the bud.
June 2	Plant now $7\frac{1}{2}$ feet high; shows serious damage, but is still healthy.	June 11	In tassel and silk; quite healthy.
June 11	Now in tassel and silk; is one of the healthiest plants in the garden.	June 21	Is bearing a large, healthy ear.
June 21	Is bearing two fine ears.		

In these two cases, at least, the plants, although much disfigured when young, were fully up to the average in productivity later in the season.

At times the feeding of the larvæ in corn buds produces a deformity resulting in the failure of the developing leaves to unroll normally, but such instances are too rare to have any bearing on the question of bollworm injury by this brood.

The injury to tassels (Pl. VII, fig. 2), which occurs later in the season, is of small economic importance also, since the few which may be partially destroyed must have but small effect on the pollen production of the field.

DAMAGE TO EARS OF CORN.

It is in the ears that the real damage and loss occurs, but this injury is frequently overestimated. In ears of early sweet corn it is not exceptional for the larva to bore directly down the ear, as shown in Plate VIII, figure 2. In this case the actual number of grains destroyed may be considerable, and the filthy excrement distributed over so large a space favors decay and subsequent molding of the ears, thus making the corn unfit for the market or table use. Feeding normally about the apical portion of the ear, the part affected scarcely ever amounts to more than one-fourth or one-fifth of the ear. But the extent to which sweet corn is infested, as compared with field corn, makes the loss to this crop proportionally heavy.

In feeding on the larger and more rapidly hardening ears of field corn, injury is usually confined to the silk and apical portion, as shown on Plate VIII, figure 1. The exact quantity consumed by each larva is not readily determined, since it is quite variable. After the eggs have hatched the silks may furnish the food until the larva is from one-

eighth to one-half grown, or sometimes even much larger, so that a correspondingly large or small portion of the kernels beneath is consumed during later development. Experiments made in the laboratory show that a bollworm may consume from 30 to 50 kernels of corn during its entire life. Allowing 900 kernels to an average ear, this would mean an injury of from 3 to 6 per cent. Often more than one larva may mature in a single ear, and again the silk may supply the greater part of the food. Taking into consideration, also, that the apical portion of the ear, which is least valuable, is the first destroyed, the injury to field corn will probably not often exceed the estimate given above, and will, of course, fall lower where the percentage of infestation is less than 100. Although the eggs are laid in the fresh silks, the larvæ scarcely ever hatch in time to destroy the silks before pollination has occurred, so that the fertilization of the infested ear is not interfered with.

DAMAGE TO COTTON.

The extent of the injury caused by a single larva to cotton bears directly on many questions of bollworm control, and has been investigated carefully by a series of experiments and observations made upon cotton growing in the laboratory garden at Paris.

The first series relates to very young cotton, and was made during late May and early June. At this time the plants were from 7 inches to 1 foot high. On May 31 two quarter-grown larvæ were placed on one of the largest plants and covered by a wire-screen cage. Both entered the soil to pupate on the 10th of June, leaving the plant almost completely defoliated, after the fashion in which the cotton caterpillar injures the plants later in the season. Although the plant was in bad condition when the larvæ left it, later in the summer it was practically as well developed as its fellows in the immediate vicinity. This and other plants similarly treated had not yet formed any squares. The other plants treated gave, on the whole, about the same results as the one described, though the average extent of injury was somewhat less.

A second and more important series of observations was made during the latter part of July and the first half of August. The plants experimented on were about two weeks earlier than the general planting, and hence were at that time in the same stage as the field crop during August, when the third generation of bollworms is most destructive; that is, when full of squares, flowers, and bolls. Six of the more complete records are given in the succeeding paragraphs:

Experiment 1.—A newly hatched larva placed on a plant 2½ feet high July 13. By the 25th it had entered the soil, after destroying twelve squares, one one-fourth grown boll, and one flower.

Experiment 2.—Small larva placed on a plant 3 feet high on July 15. It entered the soil on the 27th, after destroying one square, one small boll, and two large bolls.

Experiment 3.—A newly hatched larva was placed on a plant 3 feet high July 15. It entered the soil July 28, after destroying one square, one flower, and two full-grown bolls.

Experiment 4.—Larva one-eighth inch long was placed on plant 3 feet high July 26. It entered the soil August 4, after destroying nineteen squares. No bolls or flowers were injured, although two large bolls bore evident marks where the larva had tasted them and passed on. The daily injury done by this larva may be of interest: First and second day, one square; third day, two small squares; fourth day, one small square; fifth day, one square; sixth day, two squares; seventh day, five squares; eighth day, six squares.

Experiment 5.—A one-eighth inch larva was placed on a plant 3 feet high July 27. It entered the soil August 7, after destroying four squares, two flowers, and two bolls (one-fourth and three-fourths grown, respectively).

Experiment 6.—A one-sixteenth inch larva was placed on a plant 3 feet high August 10. By August 20 it had destroyed thirteen squares and one flower.

A summary of these six cases shows a total injury of fifty squares, eight bolls, and five flowers. This gives an average of eight squares, one and two-thirds bolls, and one flower for each developing larva.

A great individual difference in tastes is at once evident, some larvæ preferring squares entirely and others feeding more or less on bolls when both are present in sufficient quantities, as they were in all these experiments. Squares are invariably chosen by the youngest larvæ, some of them continuing when older to search out the squares and others turning their attention to the bolls. In one case a boll was attacked by a rather young larva, which afterward consumed only squares and flowers, but this is unusual. On account of their large size, a much smaller number of bolls are destroyed than squares. In fact, it was seen in one case that two large bolls and one flower served to mature a larva, while another, which fed only on squares, required nineteen.

During the experiments each individual plant was covered by a large wire-screen cage, 3 feet square at the base and 4 feet high. This prevented in great measure the escape of larvæ, and kept out any other insects which might interfere with the accuracy of the results. The cotton plants each bore from 40 to 60 squares and from 8 to 12 well-developed bolls, in addition to a varying number of flowers and small bolls. Hence it is apparent that it would require only seven or eight larvæ, feeding at the rate of those observed, to destroy nearly all of the fruit on one large plant.

NUMBER OF LARVÆ ON A SINGLE PLANT.

As before mentioned, a large number of young larvæ may be present in a single ear of corn, but of these never more than one, two, or less frequently three mature. On cotton the number present on each plant is so variable that records of this sort can have no permanent value. The injury corresponds closely to the number of larvæ, and estimates are best made by noting the extent of the injury.

RELATION TO THE NUMBER OF EGGS LAID.

The most important fact to be noted is the wholesale destruction which takes place among the young larvæ. At times when nearly one hundred eggs are present on a single ear of corn, and but two larvæ can mature, the elimination reaches 98 per cent. On cotton the number of eggs laid per plant is considerably less, and the proportion of larvæ to mature so much the greater.

PERCENTAGE OF CORN PLANTS INFESTED.

In the early part of the season, as has already been pointed out, injury to corn by the first generation of larvæ is not great, but increases later with the appearance of the second brood. This is shown in the following table, compiled from observations of over 6,500 corn plants made at Paris, Tex.:

TABLE XXVIII.—*Percentage of infestation in early corn.*

Date.	Age of corn.	Number of observations.	Number of larvæ.	Number of injuries.	Per cent of injury.
May 1	18 to 24 inches	1,000	1	1	0.1
May 13		650	2	6	0.9
May 24	2½ to 3½ feet	1,200	9	16	1.25
May 24	3 feet	170	2	2	1.2
May 24	do	200	2	2	1.0
May 24	4 to 6 feet, tasseling	650	20	20	3.0
May 31	3 to 4 feet, tasseling	1,000	35	54	5.4
May 31	3 to 5 feet, tasseling	1,000	12	14	1.4
June 16	Silk and tassel	100	33	27	27.0
July 13	Roasting ears				98.0
July 20	do	80	19	46	57.5
July 20	do	100		56	56.0
July 20	do	157	98	110	70.0
July 21	do	180	116	176	97.2
Sept. 28	do	75		75	100.0

A second table shows the percentage of infestation at a number of other localities during the latter part of the season. It includes data for localities representing practically the entire cotton belt, showing an average percentage of infestation of 78.3. The difference between the early and late corn is plainly seen, averaging only 78 per cent for a number of cases of the former and 98 per cent for the latter.

TABLE XXIX.—*Percentage of infestation of corn plants at different localities in the cotton belt.*

Locality.	Date of examination.	Age of corn.	Number observations.	Number of larvæ.	Number ears injured.	Per cent injured.	Locality.	Date of examination.	Per cent injured.	Time of planting.
Calvert, Tex	June 27	....	80	20	54	67	Elm Grove, La	June 24	50	
Comanche, Tex	July 22	Ears	500	150	500	100	Do	July 17	78	
Do	July 27	Ripe	500	42	470	94	Shreveport, La	...do	62	
Cooper, Tex	July 26	Ears	500	790	484	97	Montgomery, Ala.	Sept. 12	87	Early.
Corsicana, Tex	June 25	...do	168	47	102	60	Do	...do	100	Late.
Dallas, Tex	May 29	...do	60	58	58	96	Albany, Ga	Sept. 7	80	Early.
Gilmer, Tex	July 26	...do	500	790	484	97	Do	...do	90	Late.
Groesbeck, Tex	July 25	...do	500	.....	.....	80	Augusta, Ga	Sept. 10	90	Early.
Hempstead, Tex	May 15	...do	60	66	42	70	Do	...do	100	Late.
Ladonia, Tex	July 20	...do	.....	.....	.....	80	Memphis, Tenn	Sept. 15	75	Early.
Mineola, Tex	Aug. 4	...do	404	.....	370	91	Birmingham, Ala.	Sept. 10	80	Do.
Morgan, Tex	July 16	...do	125	74	124	99	Do	...do	100	Late.
Navasota, Tex	June 27	...do	60	30	41	68	Lake City, Fla	Sept. 14	60	Early.
Quinlan, Tex	July 30	...do	100	.....	80	80	Lakeland, Fla	Sept. 7	100	Do.
Do	Aug. 9	...do	40	185	40	100	Archer, Fla	Sept. 6	65	Do.
Rosenberg, Tex	June 29	...do	245	52	173	70	Do	...do	95	Late.
Do	July 15	...do	75	69	72	96	Batesburg, S. C	Sept. 10	90	Early.
San Antonio, Tex	June 30	...do	80	137	76	95	Do	...do	100	Late.

The progress of infestation during the season is shown by the next table, which gives results of counts made during season of 1904 on two fields near Paris, Tex.

TABLE XXX.—*Progress of infestation during season.*

Date of examination.	Age of corn.	Per cent of infestation.	Date of examination.	Age of corn.	Per cent of infestation.
May 31	3 to 4 feet high	5.4	May 31	3 to 5 feet high	1.4
June 16	Silk and tassel	27.0	July 21	Roasting ears	97.2
July 20	Roasting ears	56.0			

CANNIBALISM.

The difference in mortality on corn and cotton is mainly due to the cannibalistic habits of the larvæ themselves. When young, this habit does not manifest itself very strongly unless the bollworms are pressed for food, but after they are half-grown or larger they become extremely vicious and attack one another on the slightest provocation. If two larvæ are feeding in one ear of corn and their paths accidentally cross, they become irritated at once and snap at each other with the mandibles. Usually the larger one is victor and makes a meal of the smaller. If, as is sometime the case, both are of approximately the same size, it is not unusual for both to be so injured as to die. Even two larvæ peaceably crawling about will almost always fight if they come together unexpectedly. They do not evince any desire to hunt out their fellows, however, and it appears to be merely chance which brings them into contact. Observers have often been inclined to think that cannibalism was induced by external annoyances caused

by ants or other insects, but this does not seem probable. It seems to be simply an inherent instinct. The bollworms appear to relish the bodies of their unfortunate fellows, but soon sicken and die if compelled to subsist for a long time on this sort of food. Several were experimented on in the laboratory by feeding them on crushed caterpillars, but none so fed matured successfully.

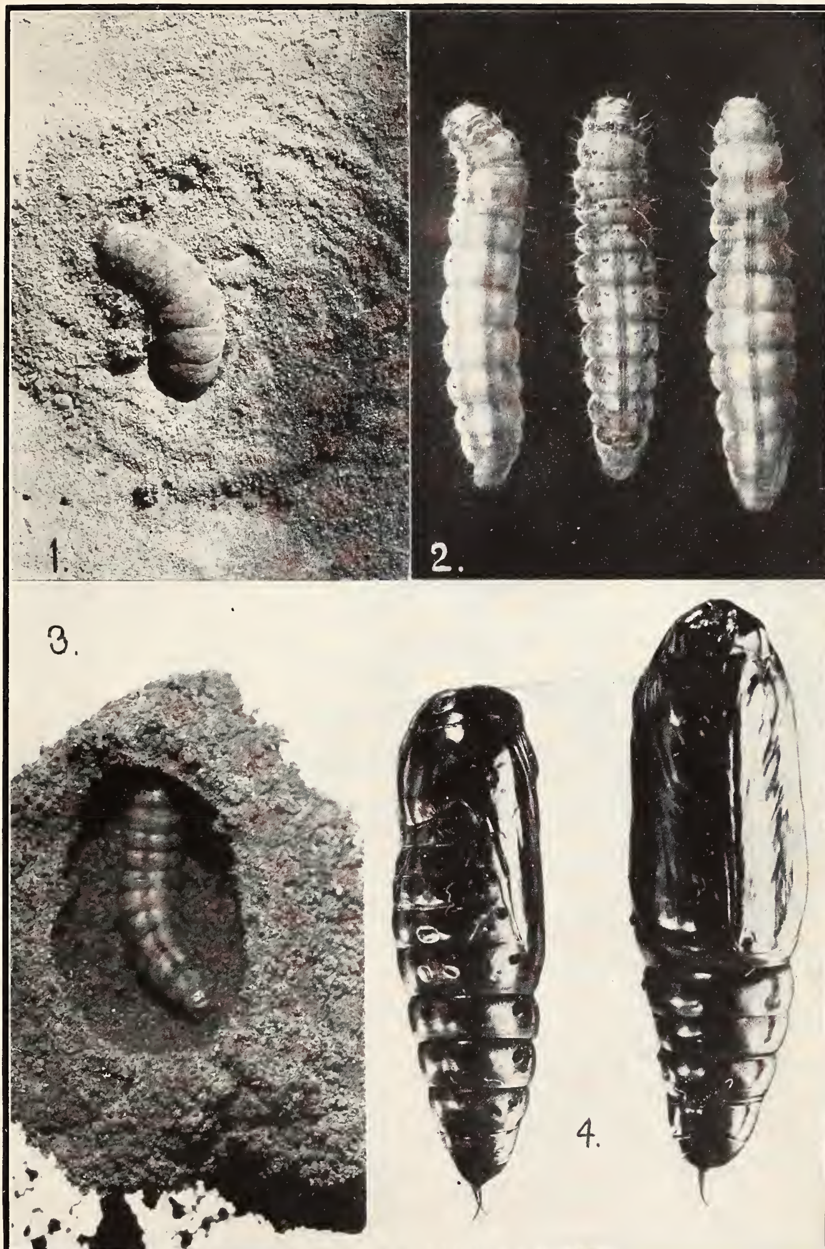
This is one of the most valuable factors in reducing the injury to corn, for if all the larvæ in an ear should feed peaceably together, as is usual among many other species of caterpillars, they would no doubt often consume it entirely. This would mean, in certain regions, an almost complete destruction of the corn crop. During August, 1904, an actual count was made of a number of corn ears to ascertain the number of larvæ present. In 10 ears there were in all 168 larvæ, each containing from 8 to 38 in all stages of development, although mostly quite small. This is an average of nearly 17 to an ear, or over eight times the number which could eventually mature.

Cannibalism is not so important in lessening injury to cotton, since the larvæ are more isolated and do not meet one another so often. During seasons of bad bollworm injury, however, it may be an appreciable factor in their reduction.

Aside from eating larvæ and pupæ of its own species, the larger bollworms will often feed extensively upon the larvæ and pupæ of the cotton caterpillar late in the fall when the latter is abundant, as well as upon other species.

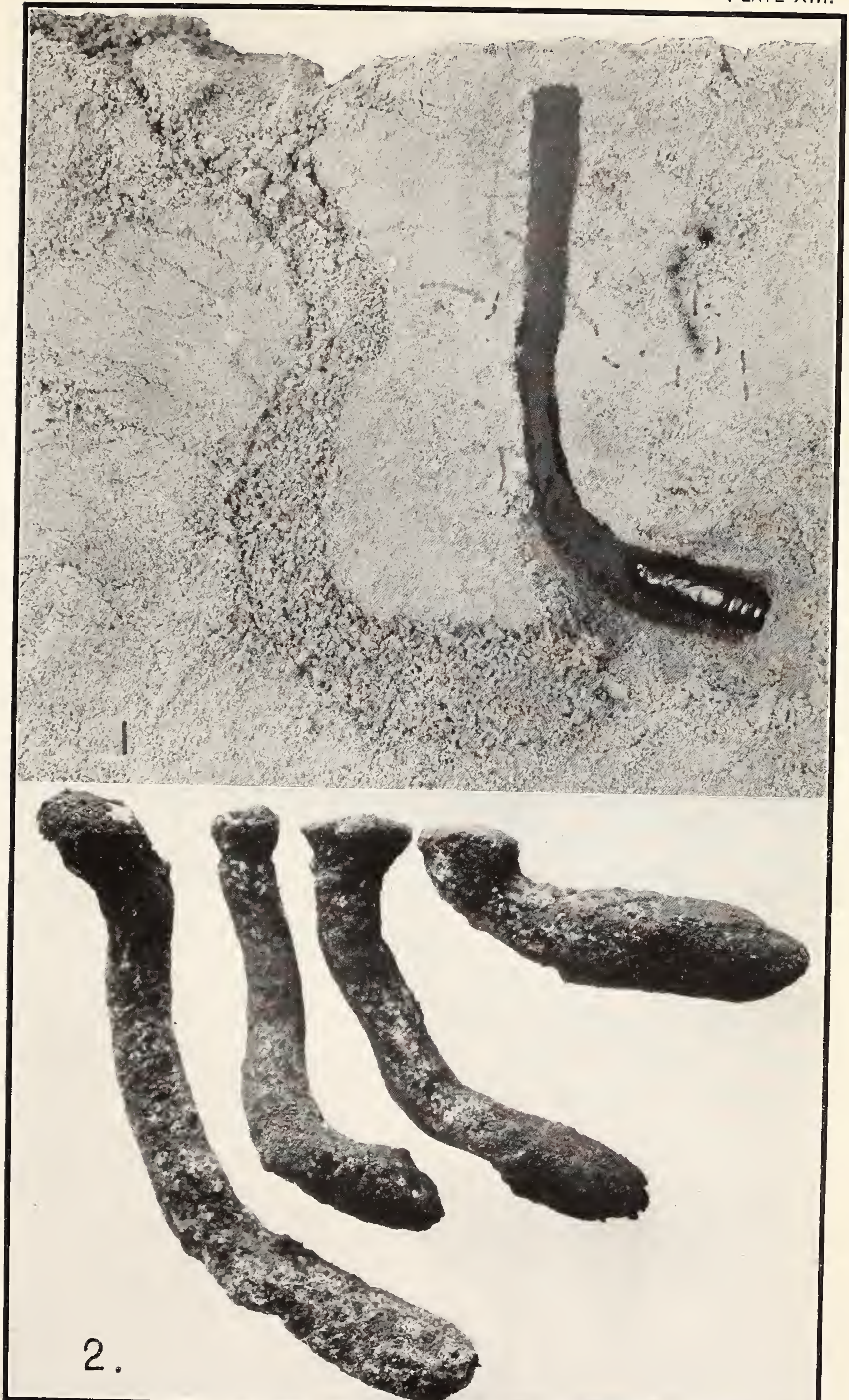
LEAVING THE PLANT AND ENTERING THE GROUND FOR PUPATION.

Bollworms feeding in ears of corn enter as very small larvæ, as already described, by eating down through the silks and between the shucks at the tip of the ear. When they are completely grown no opening for exit is present, and the larva must either eat its way out in the direction it entered or bore directly through the shuck near the tip. This last is the way usually chosen, and after the larva has emerged, a more or less sharply cut hole of the diameter of its body is left through the shuck. Only a very few crawl out through the silks, most probably because the latter are almost always decayed and moldy at this time. We were never so fortunate as to see a larva in the very act of leaving the corn ear, which would suggest that this most probably occurs at some time during the night. Whether the larva crawls down the stalk or drops directly from the ear to the ground was not determined. Comstock (Rept. Cotton Ins., 1879, p. 307) believed that they drop directly from the ear. What evidence this assertion is based upon is not given, and, to judge from the usual cautious actions of the larva when crawling about, it would seem very doubtful that they should do so. In a single instance, on August 4,



PUPATION OF THE BOLLWORM.

Fig. 1, Full-grown larva entering soil for pupation; fig. 2, three larvæ, showing shrunken appearance just before pupation; fig. 3, larva in cocoon as made in sandy soil; fig. 4, two bollworm pupæ—fig. 3 about natural size; figs. 1–2 enlarged one-half; fig. 4 enlarged three times (original).



PUPAL CELLS OF THE BOLLWORM.

Fig. 1, Pupa of the bollworm in its burrow in the soil, somewhat enlarged; fig. 2, plaster of Paris casts of pupal cells, showing variation in depth and direction, natural size (original).

1904, we saw a full-grown larva leaving a cotton plant at 9.30 in the morning. It climbed cautiously down the stem, once stopping to crawl out on a branch near the ground.

FORMATION OF THE PUPAL CELL.

Once a larva has reached the ground, it proceeds at once to select a suitable place to burrow beneath the soil. Under ordinary conditions not much time is lost in choosing the proper site, which is usually not more than 1 or 2 feet from the base of the plant. When confined within a small space a few minutes are always sufficient. It now begins to push its head against the soil, at the same time swinging it slightly from side to side, and thus throws up a pile of loosened particles of earth. (See Pl. XII, fig. 1.) The diameter of the hole when excava-

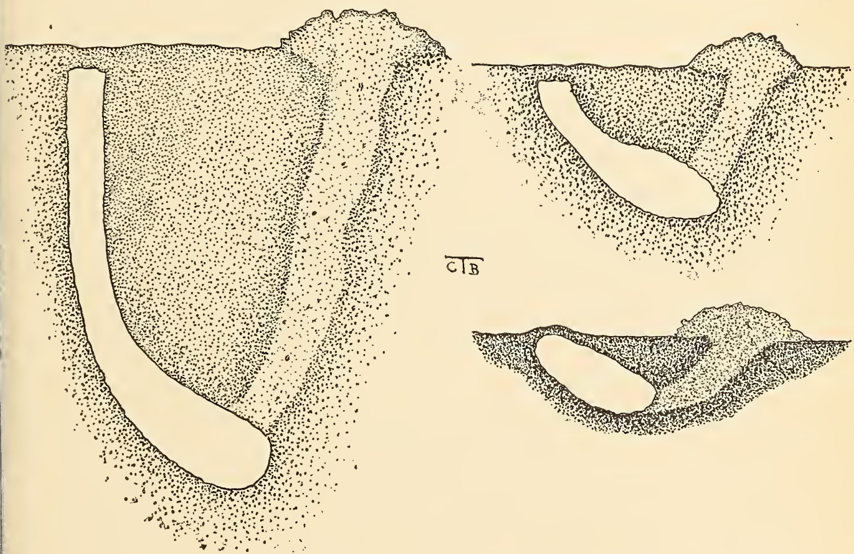


FIG. 8.—Diagram of different types of pupal cells (original).

tion begins is about twice that of the larva, but soon becomes blocked up by the loose earth. The time required to get beneath the surface varies anywhere between five minutes and three-quarters of an hour or even much longer, depending on the texture of the soil and the activity of the larva. When it has passed from view beneath the surface it continues to work down in a more or less slanting direction to a depth of from 1 to 7 inches, leaving the pile of loose earth to mark the point of its entrance. So far all its actions have been preliminary to forming the pupal cell, which is not constructed along the path by which the larva entered the soil, as had been generally supposed.

Instead it now works upward, forming a curved tunnel, with smooth walls of well-packed earth webbed together by a thin coating of silk. (See Pl. XIII, fig. 1.) Normally the tunnel stops abruptly about one-eighth or one-fourth of an inch below the surface, leaving a thin wall of earth through which the moth must penetrate on emerging. As soon as the burrow has been completed, the larva repairs to the lower end (Pl. XIII, fig. 1) and there transforms into the pupa, which lies in the cell, with the head slanting upward, until the emergence of the moth. A number of plaster casts of pupal burrows were made, and a few of them which show the typical variations in shape and size are figured on the accompanying plate (Pl. XIII, fig. 2).

VARIATIONS IN THE FORM OF THE PUPAL CELL.

There is a very evident relation between the moisture content and character of the soil and the form of the pupal cell. In dry soil of a sandy nature the larvæ always dig deeper than in moist soil of the same composition. (See fig. 8.) In the "black-waxy" soil of north Texas very shallow burrows were made, due no doubt to the mechanical difficulty offered by its tough consistency. In some cases the larvæ could make no impression on dry, baked soil of this kind and were compelled to crawl into the cracks caused by drying.

In the accompanying table are given the dimensions of eight pupal cells made in moderately moist sandy loam. They were obtained by making plaster casts of the cells. These show a considerable individual variation. They average 46 mm. in depth and 43 mm. in horizontal extent.

TABLE XXXI.—*Dimensions of pupal cells.*

Vertical extent.	Horizontal extent.
Millimeters.	*Millimeters.*
53	48
71	57
80	50
38	40
26	43
20	39
57	27
20	39

Temperature also exerts an influence on the depth of the burrow. Larvæ of the late fall brood dig much deeper than those pupating earlier in the season. In a lot of seven overwintered pupæ, at Hetty, Tex., the depth of the respective cells in millimeters was as follows: 50, 50, 125, 125, 125, 150, and 175, with an average of 114 mm. At Paris, Tex., six cells averaged 80 mm. in depth in black clay loam, and 13 in sandy loam averaged 98 mm., as compared with 46 mm. for the August brood. The reason for this is evident, since the overwintering pupæ must withstand many adverse conditions to which the summer broods are not exposed.

PUPATION IN OTHER SITUATIONS.

While it is the normal habit of the bollworm to burrow beneath the soil to pupate, it will rarely, either from necessity or otherwise, choose other situations. Coquillett (Ins. Life, I, p. 331) records four pupæ of the late fall brood which were found by him in ears of corn at Los Angeles, Cal. Probably the warm winter climate of that region may be a factor in developing such an unusual habit. In several instances larvæ confined in the laboratory with corn ears as food, but without earth, have pupated in a cavity eaten out of the ear. When this is done usually small bits of the surrounding tissues, or of paper, if such is present, are webbed together to form a sort of cocoon which more or less successfully conceals the pupa. In all our experience, however, not one was observed which had pupated in a cotton boll. This is probably on account of the rapid decomposition undergone by the injured bolls. In practice we obtained great numbers of pupæ by confining large larvæ under inverted tumblers supplied with sufficient food, but without soil.

CHANGES UNDERGONE IN THE FORMATION OF THE PUPA.

At the time it enters the soil the larva is somewhat stouter than it was just before, and the incisions between the body segments are beginning to become more distinct. (See Pl. XII, fig. 2.) When it has formed its cell a period of quiescence ensues, which usually lasts for from two to four days for the summer broods and much longer for the fall brood. During this time the larva decreases in length, gradually approximating the length of the pupa, and at the same time becoming stouter in the middle and more tapering distally, the inter-segmental constrictions growing more apparent. (Pl. XII, fig. 3.) The coloring generally becomes less brilliant and tends toward a greenish or yellowish tint with black markings.

The larval skin splits medially along the dorsum of the thorax and the head of the pupa is passed through the opening, after which the skin is rapidly worked backward by the movements of the body, finally forming a loose mass at the base of the cremaster, where it is easily thrown off entirely. This operation is all accomplished in the brief space of four or five minutes. The pupa is now very pale in color, usually with the head and thorax lemon-yellow, or often distinctly greenish, especially on the thoracic dorsum and appendages, with the spiracles brown and the abdomen creamy yellow. After an hour or two the abdomen has darkened considerably, the integument assuming a brown color and concealing the fat bodies beneath. From twelve to eighteen hours are required for it to gain the uniform brownish tint, which continues to darken for several days longer. Pupæ forming late in the fall do not undergo this final darkening until a short time before emergence the next spring.

THE PUPA.

The pupa is similar in color and form to those of the vast series of other Noctuid moths, and consequently is very difficult to describe in a way which will permit of positive identification. The following description is condensed from one drawn up by Mr. Girault based on a large number of specimens.

DESCRIPTION OF PUPA.

(Pl. XII, fig. 4.)

Length, 14 to 23.4 mm., excluding the cremaster; average, 18.97. Body shining reddish brown, darker above the incisions; the head, spiracles, and cremaster with a very dark median line above which fades out behind; wing covers often paler.

Head finely transversely roughened, with several oblique striæ. Toward the middle line in front of the insertion of the antennæ are two short delicate setæ arising from minute punctures, and just before the hind margin is an indistinct crescentic impression. Just before the insertion of the antennæ are three more or less distinct longitudinal lines reaching as far as the eye.

Thorax more densely corrugated than the head, with a more or less distinct median carina which shows from above as a darker median line. Prothorax impressed along the anterior margin and bearing behind the middle a pair of minute median setigerous punctures placed on minute depressed rotato-rugose pimples; also a similar setigerous puncture just in front of the spiracle. Mesothoracic dorsum at anterior third, with a more or less distinct coalescent pair of raised roughened areas; a margined setigerous puncture toward the lateral margin; behind these at the base of the wing covers are four shallow foveæ, three of them sometimes placed in a triangle. Middle of dorsum with two more or less distinct, short, diverging furrows on each side. Metathoracic dorsum irregularly corrugate, more finely sculptured on the lateral lobes, with a setigerous puncture near the base, central to the lobes, with covers very finely and irregularly sculptured, highly polished.

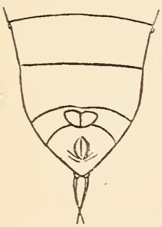


FIG. 9.—Enlarged caudal end of pupa (original).

Abdomen above irregularly transversely aciculate, the anterior margins of segments 4–7 coarsely punctured above, and of segments 5–7 below; eighth and following segments connate, the last bearing the cremaster at its apex. Tip obliquely truncate below; penultimate segment with a similar raised space less sharply divided at the middle.

Cremaster consisting of two slightly curved spines, their extreme tips bent at right angles; very dark on basal half and paler distally (see fig. 9). Length, 0.9–1.24 mm.

The weight of 21 pupæ of the second generation freshly dug out of the soil was 9.24 grams or 0.44 gram each, 64 of them together weighing an ounce.

LENGTH OF THE PUPAL STAGE.

The time passed in the ground after the larva has made its burrow until the moth emerges varies from a period of less than two weeks for the summer broods to about six months in the case of the hiber-

nating generation in the cotton belt, and this period for northern localities is still greater.

Data collected at the laboratory for over a hundred individuals at different times during the season are summarized in the following table:

TABLE XXXII.—*Duration of pupal stage.*

Larva in soil.	Moth emerged.	Average time.	Pupal stage.	Effective temperature.	Larva in soil.	Moth emerged.	Average time.	Pupal stage.	Effective temperature.
		Days.	*Days.*	° *F.*			*Days.*	*Days.*	° *F.*
May 8–10	May 31	22	....	662	June 18–21.	July 4–7	15	....	621
May 13–16	June 2–6	$20\frac{1}{3}$	....	770	July 18	Aug. 2	$14\frac{1}{2}$	....	607
May 19	June 7–9	20	....	653	July 27–29	Aug. 12–15	16	....	631
May 21–22	June 6–10	18	....	598.6	Aug. 5	Aug. 20	15	....	606
May 26	June 11–15	$17\frac{1}{2}$	14	615	Aug. 8	Aug. 25	$16\frac{1}{2}$	....	708
May 30–31	June 17–20	19	$14\frac{1}{2}$	665	Aug. 17–19	Sept. 1–3	15	....	639
June 3–4	June 20	$16\frac{1}{4}$	16	605	Sept. 7	Sept. 20	17	16	621
June 10	June 24	14	13	530	Sept. 20	Oct. 16	26	....	885
June 15	June 24–July 3.	15	13	588	Sept. 29	Oct. 23	25	20	724

It will be noticed that the records in the third column include the time between the entrance of the larva into the soil and the emergence of the moth, while the time for the true pupal stage, shown in the fourth column, is somewhat less. The exact time is usually hard to

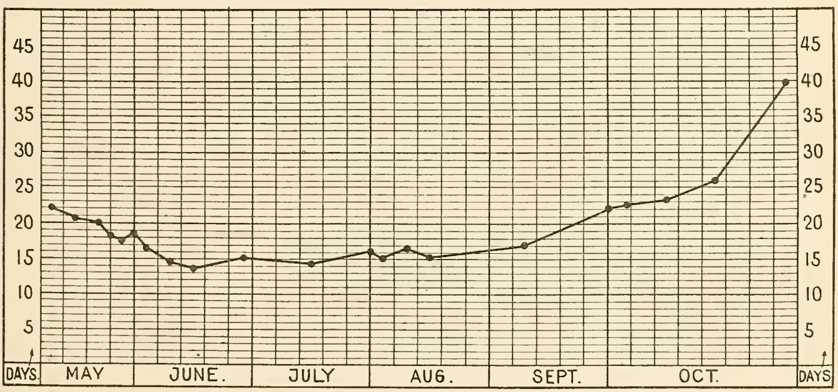


FIG. 10.—Chart showing relative length of pupal stage during season of 1904, Paris, Tex. (original).

determine, however, without disturbing the pupa concealed in its cell. Under normal conditions the quiescent stage, after the burrow is completed, lasts from a few hours to five days.

The comparative length throughout the season at Paris, Tex., of the stage passed in the ground is shown in figure 10.

During 1903 a series of pupæ observed at Calvert, Tex., passed through this stage in ten and a half days, a shorter period than any observed at Paris, due no doubt to the more southern locality.

EFFECT OF EXTERNAL CONDITIONS.

The influence of varying temperatures on the length of the pupal stage is exceedingly interesting and instructive, the pupa being apparently much more uniformly affected than the other stages. This is evident from the close agreement between the sums of effective temperatures given in the preceding table.

On July 20, 1904, three recently formed pupæ were placed in the laboratory ice box and left there for thirty-five days at a temperature averaging about 57° F. They then showed no signs of emerging and were removed to the temperature of the laboratory, where the moths appeared after from five to eight days. They must have been developing slowly in the refrigerator, as the seven days during which they had been at normal temperatures would not otherwise have been sufficient for development. Calculations based on this experiment compared with several other lots of pupæ that developed at normal temperatures show that development is apparently almost prevented by low temperatures and suggests that the growth of the pupa is determined with reference to a higher temperature than the 43° F. usually chosen. This is shown as follows:

TABLE XXXIII.—*Effective temperatures for pupal development.*

Length of stage.	Sums of effective temperatures. Above 43°.	Above 58°.	Above 60°.
	°	°	°
May 9 to 13	662	317	271
June 10 to 24	530	305	275
September 29 to October 23	724	349	300
Ice-box experiment	1,341	359	308

It will be noted that the sums are more nearly equal when 58° or 60° are assumed to mark the inception of metabolic activity.

During September, 1904, the influence of extreme cold was tried in two cold-storage vaults at temperatures of 34°, 27°, and 18°, respectively. The results obtained are tabulated below:

TABLE XXXIV.—*Effect of low temperature on pupæ.*

Temperature conditions.	Larvæ in cells. Total.	Moths emerged. Perfect.	Moths emerged. Deformed.	Remained—live pupæ.	Mortality.	Pupæ in loose earth. Total.	Moths emerged. Perfect.	Moths emerged. Deformed.	Remained—live pupæ.	Mortality.
					Percent.					*Percent.*
A. Placed at 34° for 48 hours	19	4	0	4	58	14	2	1	0	79
B. Placed at 34° for 24 hours, then at 27° for 96 hours	23	4	1	1	74	14	0	0	0	100
C. Placed at 34° for 24 hours, 27° for 24 hours, then 34° for 72 hours	21	12	0	3	29	14	0	0	0	100

Although the sudden change from summer temperature to freezing was quite abnormal, the difference in results from the three lots is very instructive with respect to the pupæ in loose earth and those in the cells. Not a single pupa survived freezing in a broken cell, while a number successfully withstood it when resting in their cells. The effects of this cooling did not disappear at all on the pupæ which had failed to emerge within a month after removal from cold storage, and they passed into winter hibernation.

Later in the month the experiment was practically repeated with a box containing about thirty pupæ, half of them in normally constructed cells and the others buried under an inch of moist soil. The box was first cooled at a temperature of 34° for twenty-four hours and then frozen at 27° for three days. No moths appeared until December 10, when a male moth emerged. Four days later the pupæ were examined and it was found that three live ones still remained in their pupal cells, while all those buried in loose earth had been killed.

HEAT.

The effect of hot sunshine on pupæ was tried during August, 1903, at Calvert, Tex. Three pupæ, two days old, were placed on the hot soil at noon where the sun shone on them and left for a period of ten minutes. On removal to normal surroundings at a subsequent examination all were found to be dead, due, no doubt, to the heat.

Experiments show, however, that pupæ can withstand heat much more readily under conditions of great humidity. Twenty healthy pupæ were covered with about half an inch of loose damp soil and left where the sun could strike them. During the next five days two good rains fell, after which the pupæ were examined. Sixteen were alive, one was parasitized, and two were dead. On another occasion four pupæ were placed in artificial cells in the laboratory garden where the sun could strike them and covered with a bell jar. In spite of the humid atmosphere and heat three perfect moths emerged.

SOIL.

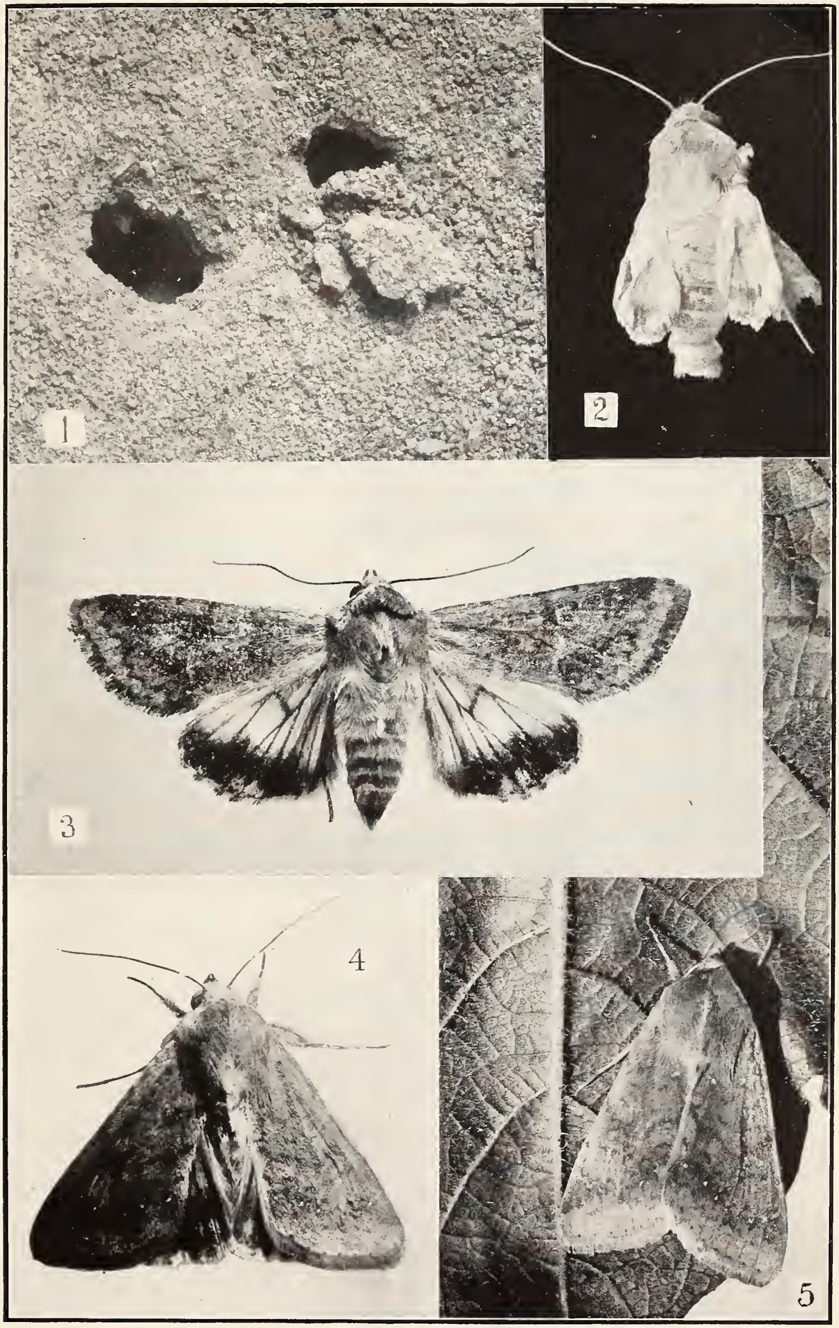
The moisture content of the soil does not seem to influence the length of the pupal stage. Of two boxes, each containing twenty pupæ in normal cells, one was watered and kept continually damp, while the other was left to dry. From the dry box there emerged thirteen moths, and from the wetted one, eleven, the pupal stage being nineteen days in each case. However this may be, it has been noticed that lots of pupæ which have been under dry conditions until about ready to emerge will often do so more quickly if the ground be wetted.

When the pupal cells have been broken up the distance which the emerging moths can work their way through the soil depends almost entirely on the consistency of the latter. Very loose, friable, sandy soil seems to offer no obstacle at all, as the following experiment will show. Two lots of nine pupæ were placed in separate jars, buried beneath 2 and 4 inches, respectively, of dry, finely broken sandy loam. In each jar seven perfect and one imperfect moth emerged. If the earth is damp and packed down upon the pupæ, either by rains or otherwise, the result is very different. One box containing sixteen pupæ covered with 1½ inches of soil and thoroughly wetted was allowed to dry hard. Only two perfect moths emerged, the three others which emerged failing to expand their wings. The others were found embedded in the soil in their split pupa cases, from which they had been unable to escape. Other scattered observations show that from 2½ to 5 inches of moderately moist, heavy earth will almost entirely prevent the emergence of perfect moths.

The effect of submergence under water was also tried upon pupæ in cells and loose in the black soil of the sort occurring in the river bottoms that are subject to yearly overflow. In each case the earth was covered to a depth of 1½ inches with rain water. At normal summer temperatures the pupæ could not withstand twenty-four hours' submergence, but in the ice box, at a temperature of from 50° to 60° F., they were unharmed by from four to six days' submergence.

MORTALITY DURING THE PUPAL STAGE.

Under normal conditions mortality during the pupal stage is but slight, although a number of larvæ die in their underground cells before pupating. In a lot of forty larvæ entering the soil during the latter part of July, only twenty-four, or 60 per cent, emerged, while of larvæ which successfully pupate from 80 to 90 per cent usually emerge. The mortality among the hibernating pupæ under normal conditions must be very much greater. In one case twenty-five larvæ nearly or quite full grown were placed in a box with food on October 30, 1903, and the box sunk level with the soil, at Hetty, Tex. No moths having emerged by June 2, 1904, the pupæ were exhumed and only two live ones found, one of which later failed to emerge. Traces of five others were found. Of a second lot, five larvæ entering the soil at Victoria, Tex., November 5, 1903, not a single one survived the winter. In a third lot at Calvert, Tex., consisting of seven pupæ buried in loose earth, November 3, 1903, but two survived the winter, while of twenty-five larvæ left to pupate at the same time, ten had pupated and survived. The results shown all point to a much greater mortality for this generation, although much seems to depend on local conditions.



THE BOLLWORM MOTH.

Fig. 1, Exit holes of moths, made in escaping from pupal cells in ground; fig. 2, condition of moth immediately after its emergence from soil; fig. 3, bollworm moth with wings expanded; fig. 4, moth, showing alert position when disturbed; fig. 5, moth at rest on cotton leaf—all figures about twice natural size (original).

NINE BOLLWORM MOTHS, ARRANGED TO SHOW VARIATION IN COLOR AND MARKINGS, NATURAL SIZE (ORIGINAL).

THE ADULT.

EMERGENCE.

The method of emergence of the moth has been already referred to under the discussion of the pupa. Under normal conditions the pupa, resting at the lower end of its subterranean burrow, splits the pupa case along the median dorsal line of the thorax, and the moth, escaping, with still unexpanded wings crawls up to the top of the burrow. Here it must break through the thin wall of earth before reaching the surface of the soil. The moths are very strong and have no trouble in loosening a piece of the thin crust, making an aperture through which they accomplish their exit. The openings through which two moths have emerged are shown on Plate XIV, figure 1. Once out, the moth is perfect, with the exception that the wings are unexpanded (see Pl. XIV, fig. 2). After a few minutes the wings have become extended to their full size, and several hours later the moth is able to fly (Pl. XIV, figs. 4 and 5). If disturbed before the wings are strong enough for flight, the moths are very active and can run about with surprising agility.

There is a well-marked tendency among moths toward emerging during the night and very early morning. About twenty appear during these parts of the day, compared to six which come out later.

DESCRIPTION OF MOTH.

As has been already mentioned in the earlier pages of this bulletin, the bollworm moth is extremely variable in color and markings (see Pl. XV). Of the five varieties there enumerated, but two, or possibly three, have been met with in Texas. The commonest variety is *ochracea* Ckll., thirty-five in a lot of sixty-five being referable to it, some of them very dark in color and apparently approaching the European *fusca* Ckll. The remaining thirty are variety *umbrosa* Grote.

Individuals belonging to these different forms have been reared from eggs deposited by the same female, and there can be no doubt that they interbreed with perfect freedom.

In *ochracea* the wings have an ochraceous or reddish tinge which is often quite coppery in very dark moths. The hind wings are always rather strongly marked, the apical band very distinct, and the wing veins usually lined with black. The front wings have in the darker specimens a very distinct transverse dark band, but in lighter individuals this is often scarcely at all evident. The stigmal spot is often absent and never strongly marked. Beneath, the wings have a subapical cross-band, less distinct on the hind wings, and a very distinct sublunate spot.

The specimens referable to variety *umbrosa* have a more olivaceous cast and are generally lighter in color. The stigmal spot is nearly always very plainly marked and the cross-band of the front wings more or less obsolete. The black apical band of the hind wings is not so pronounced as in *ochracea.* Beneath, the markings are about the same, except that the band on the front wing is weaker and the one on the hind wing nearly always obsolete.

More of the females fall in the *ochracea* group and more of the males under *umbrosa.*

SIZE OF MOTHS.

Measurements of a series of 100 moths gave the following sizes:

TABLE XXXV.—*Comparative sizes of bollworm moths.*

Sex.	Wing expanse.			Length.		
	Largest.	Smallest.	Average.	Largest.	Smallest.	Average.
	Millimeters.	*Millimeters.*	*Millimeters.*	*Millimeters.*	*Millimeters.*	*Millimeters.*
Male	47	30	40.42	21.9	13	18.5
Female	46	34	40.86	20.5	14.5	17.89

From this it can be seen that the males are considerably more variable in size than the females. In wing expanse they average a little smaller, but in length greater, probably on account of their longer and more slender abdomen.

VARIATION AND POSSIBLE CAUSES.

In spite of the very apparent variation of the moths, the causes which govern this variation are very obscure. Riley[a] thought that those moths feeding on corn in the Western States were darker and more brightly colored than those of the cotton belt. In our experience in breeding no constant difference was noticed between moths bred from larvæ raised on corn and on cotton under the same climatic conditions.

On several occasions it was noticed that moths emerging from pupæ which had been placed in cold storage and kept at a low temperature for several days proved to be much darker than any specimens we had seen elsewhere. On the other hand, no especially dark individuals are to be noticed among the moths of the spring brood whose pupæ have been subjected to the gradually lowering temperature of the winter months. This shows plainly that the moths may be influenced by temperature, but it is evident that there are other factors concerned also.

To ascertain whether there was any relation between the extremely variable color of the larvæ and the color of the moths, the color of a

[a] Fourth Report, p. 371.

number of bollworms was noted and they were then allowed to pupate separately. After emergence a comparison was made, but it failed to show even the slightest relation.

ANATOMY AND SEXUAL DIFFERENCES.

It is beyond the scope of the present bulletin to consider in detail the anatomy of the bollworm moth. Most important in relation to the economic position of the insect are the organs concerned in feeding and reproduction. In common with other lepidopterous insects, the bollworm moth feeds only on liquids, which are sucked up through the long, flexible proboscis. The latter is about three-fourths as long as the body and when not in use is coiled tightly beneath the head. When feeding it is held out nearly straight, a little curved near the tip, which is applied to the nectaries on the squares when feeding on cotton. Owing to the considerable length of the proboscis it can also reach well within the cotton flowers. The food is drawn into the proboscis by means of the large muscular pharynx which acts as a pump.

The pharynx connects with the food reservoir, or stomach, by a slender œsophagus. If overfed, as is often the case when food is plenty, the stomach becomes greatly swollen.

In the female almost the entire cavity of the abdomen is filled by the ovaries. These organs consist of eight long tubules, four to each side of the body, although owing to their great length they are coiled and folded upon one another many times. Near the tip of the abdomen they unite to form a single tube through which the eggs pass one by one, as they are laid. The more mature eggs are near the end of each tubule and those still in the process of formation near the farther and more slender tip. The distal portion of the oviduct is hard and chitinized, forming the ovipositor, by means of which the eggs are placed on the plants. When the moth emerges the eggs in the ovaries are small, but develop rapidly during the first day or two, at the end of which time oviposition may begin. From counts made of the eggs present in newly hatched moths, it seems probable that there is a continual formation of new eggs during life.

In the male the abdomen is usually narrower than in the female and the sides are more nearly parallel instead of bulging. The tip is also less pointed and more squarely cut off. The amount of food in the abdomen, however, very often conceals these characters, and others must be relied upon for the separation of the sexes. A second character which is sometimes available is the presence of certain spines on the front margin of the wing near the base. In the male there is a single long curved spine and in the female two equal smaller ones on each hind wing. They are not always easy to see, however, and are easily broken off. When such is the case it is necessary to resort to dissection to be positive.

In the male the genitalia are quite peculiar and consist of two fan-like lamellæ, thickly fringed with long pale ochraceous hairs, which partially inclose the claspers (fig. 11). When everted the tufts of yellow hairs are very noticeable, but at rest they are almost completely retracted within the abdomen.

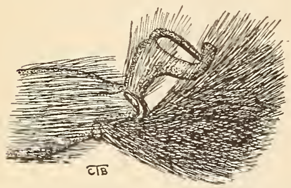


FIG. 11.—Genitalia of male bollworm moth (original).

Copulation was observed only once, in a small bottle and under very abnormal conditions. The moths were united end to end, as is the usual habit among moths. Many other individuals have copulated in the breeding jars in the laboratory, but never when under direct observation.

PROPORTIONS OF THE SEXES.

A number of observations were made and data concerning over 300 moths were collected which bear evidence on the proportions of the sexes. These include records of moths collected in the field and of those bred out in the laboratory. In practically all cases there is a slight preponderance of females in the ratio of 168 females to 120 males. Since the sexes are not readily distinguished externally, that of each specimen was determined by dissection. It might be suggested that the small number of males may be due to their greater agility in eluding capture in the field, but the records from the laboratory breeding do not bear out such a conclusion.

LENGTH OF LIFE.

The life of the moths seems to be determined almost entirely by the external conditions after emergence, especially by the supply of available food. During the season some eighty specimens were kept in breeding jars in the laboratory and subjected to variable conditions in order to ascertain the length of life. A short summary of the results is given in the table below.

TABLE XXXVI.—*Average length of life of moths in laboratory, 1904.*

Month.	Males.		Females.	
	With food.	Without food.	With food.	Without food.
	Days.	*Days.*	*Days.*	*Days.*
May	7½	3¾	9¼	5¼
June	12	4½	16	3
July	10	4	12	6
August	14½	4	13	6
September	11	....	18	....
October	10½	....	11¼	....

Longest life of males, 19 days 12 hours, during September.
Longest life of females, 38 days, during September–October.

From this it is apparent that the first generation is distinguished by its much shorter life, but with regard to any other generation it is not safe to generalize, except possibly to mention that the longest individual records were made during the month of September.

During September Mr. Girault experimented on a series of twenty moths, each of which was subjected to different conditions of food supply. His results are given below.

TABLE XXXVII.—*Effect of food conditions on length of life of moths.*

Lot.	Number and sex of moths.	Food given.	Length of life.			Range.	Eggs deposited.
			Males.	Females.	General average.		
			Days.	*Days.*	*Days.*	*Days.*	
1	1 female, 3 males	None	6	4½	5¼	3 to 6⅔	23
2	All females	Water for one day		6⅓	6⅓	4½ to 9½	91
3	2 males, 2 females	Sirup one day	6½	8¼	7⅔	6½ to 8½	160
4	2 males, 2 females	Water every day	9½	10½	10	7 to 12¼	10
5	2 males, 2 females	Sirup every day	17⅓	30	23⅔	17 to 38	866

It is at once seen that the length of life increases as we pass down the columns, but that oviposition is not really begun until food is obtained, for it will be noticed that moths given only water laid practically no eggs, although they lived longer than those fed once on sirup. This one feeding, however, sufficed to induce considerable oviposition.

The apparent necessity for a continuous food supply is a factor which is very important in relation to the feeding habits of the moths in nature, and will be referred to again in connection with the use of June corn and cowpeas as a trap crop.

One point which may be mentioned in passing is the gluttony of the moths when given abundant food. The sirup or sugar solution used in the laboratory had to be given very sparingly, otherwise the moths would gorge themselves, and the subsequent fermentation of the sugar which could not be digested would invariably cause premature death.

DAY HABITS.

During the daytime the bollworm moth is usually very quiet, resting immovable in more or less concealed places. During the early part of the summer, corn, which is still in the "bud," furnishes the favorite hiding place. Here the moths remain well down in the central cavity or between the still closely curled leaves. The insects rest with the head up and the wings tightly folded down over the back. In this position they often remain during the entire day unless molested or frightened. A jarring of the plant, or any unusual disturbance, however, quickly awakens the resting moth, and hastily leaving the plant it flies wildly until it chances upon another, where it quickly insinuates itself into the bud by a series of zigzag backward move-

ments. For a few moments afterward, until it has regained its composure. the wings are held somewhat apart and vibrate rapidly (see Pl. XIV, fig. 4). If again disturbed while thus on the alert, the second flight is usually longer, and the moth will fly for a hundred feet or more before alighting. When the corn plants grow larger and the tassels and silks are formed, the moths are usually concealed at the base of the leaves close to the stalk. Later in the season the moths most frequently hide during the daytime in cotton fields, patches of cowpeas, or weeds in fence rows. In cotton or cowpeas the leaves afford abundant shelter and the moths are usually to be found resting on the upper side of one leaf in the shadow of another. (See Pl. XIV, fig. 5.) More rarely they may be observed hanging to the flowers or squares. When disturbed, they dart down along the rows or between the plants, losing no time in choosing a second hiding place. They are so quick in getting concealed that they sometimes disappear as if by magic, especially where the foliage is dense.

It is only rarely that moths are to be seen feeding or ovipositing in bright daylight. But at periods when food is scarce a number of moths are usually active during the day. They have been seen feeding on the following plants in the daytime: Alfalfa flowers; cotton; cowpeas; *Eupatorium serotinum*, a common roadside weed; wild sunflowers; and *Solanum rostratum*, another roadside weed. On corn they have been observed to feed on the sweet secretion of *Aphis maidis* Fitch and *Dicranoptropis* (*Delphax*) *maidis* Ashm., and on drops of rain and dewdrops upon grass. Cockerell records them feeding on plum blossoms at Mesilla Park, N. Mex., early in April.

NIGHT HABITS.

At about 4 o'clock in the afternoon, when the heat of the day has passed, the period of activity for the moths begins, and continues until well into the night. Sometimes, however, activity does not begin until much later, often not until half-past 6 or 7 o'clock. It is quite noticeable that during periods when food is scarce, owing to drought or other causes, the moths are out earlier than at other times. In fact, their entire attention is given to feeding at first, after which the females begin to alternate this with periods of oviposition, as has been described in the preceding pages. The males no doubt continue to feed until the females are well started on their work of egg-laying, but after oviposition has become quite general males on the wing become scarce.

During the process of feeding the moths fly in much the same way as when ovipositing. On cotton only the squares and flowers are visited, no notice being taken of the nectaries on the under surface of the leaves. Alighting on a square, the moths seek out the nectaries, and if nectar is present each bract is usually visited in succession. If

the nectary is dry, however, no time is wasted before seeking another. In feeding on the flowers, the proboscis is inserted into the corolla, usually near the base between the petals. In such situations the moths are no doubt searching for moisture rather than honey. It is rare for the moth to visit more than three or four parts of one plant before flying away, although quite often it will return to a plant previously fed upon. During the course of an hour a moderately active moth, alternately feeding, resting, and ovipositing, will cover several acres of ground, visiting anywhere from one hundred to one hundred and fifty plants.

Early in the evening, when the moths are first on the wing their flight is very swift, but gradually slows down. As a general rule they are quicker and shyer on the clear evenings following hot, dry days, and less active in cloudy or rainy weather. This does not indicate a decrease in oviposition in rainy weather, as might appear at first sight, for rapid flight does not determine active oviposition.

Night feeding is confined almost entirely to corn and cowpeas early in the season and to cotton and cowpeas later. Corn offers no primary attraction in the way of food, but they feed upon the moisture present and upon the honey dew of aphids. The honey secreted by the glands on the fruit stalks of the cowpea draws them to the plants, although, as before noted, oviposition is not common on them. Cotton must also offer a great attraction by supplying food, aside from any other consideration. At the time cotton is squaring and blooming extensively other food is scarce, and for this reason alone the moths may be induced to turn their attention to it.

ATTRACTION BY LIGHTS.

Although the uselessness of trying to capture the moths by means of trap lanterns has been pointed out again and again, the method was tested very thoroughly during the year. Several tin traps were constructed like the one shown on Plate XXV, figure 1, somewhat similar to a model described by Gillette, with the addition of a patent oil-torch lamp and a series of tin reflectors above. The lower portion was well stocked with cyanide, and the lamps put in operation in corn and cotton fields at various dates during the season. The first night, May 2, a single male Heliothis was captured, but the traps yielded no further moths in fifteen future settings, and were abandoned until later in the season. During the early part of September the traps were again resorted to with less discouraging results, 8 males and 2 females being caught in four settings. At this time, however, moths were present in countless numbers in the patches of corn and cowpeas where the traps were placed. Aside from these captures, 3 single female specimens were collected at different times flying to the lights in windows

of dwellings. All observations serve to show that the attracting of the moths to ordinary oil lights is an utterly hopeless task.

Brilliant arc lights are an attraction, however, and during the early part of August, at Paris, along the business street, within a space of four blocks, sometimes as many as forty or fifty of the moths could be counted near the lights. Saloons and fruit stands offered especial inducements, no doubt on account of the odors of fermenting fruit, etc. Professor Morgan[a] mentions à similar instance:

> Last season, in collecting by an electric light on the university campus, under which the crab grass had been permitted to grow and go to seed, great numbers of a light-colored moth were seen to be perched upon the heads and stems of the crab grass, from 20 to 50 feet from the arc light. Upon collecting a few they were found to be specimens of the bollworm moth. * * * During the entire evening not a single specimen was seen to fly up to the light, but all remained at some distance from it.

Chittenden[b] also states that during the latter part of September, 1900, bollworm moths formed about 16 per cent of the total number of moths attracted to the electric street lights at Washington, D. C.

We have had experiences similar to the one noted by Professor Morgan. During early September it was observed that the corn plants for a distance of 50 feet surrounding the lantern traps were well supplied with hiding moths the day after the traps had been in operation, although hardly any moths had been caught in the trap itself.

ATTRACTION BY POISONED SWEETS.

All attempts to trap the bollworm moths in this way have yielded absolutely negative results. During the latter part of the summer quite a number of experiments were tried with different combinations in varying proportions of New Orleans molasses, sorghum, vinegar, and beer; some of them poisoned by potassium cyanide or cobalt, and others not. The solutions were placed in flat pans elevated on pedestals from 1½ to 4½ feet high (see Pl. XXV, fig. 2). None of them attracted more than an occasional stray moth, although they were placed in fields of corn and cowpeas where the moths were extremely abundant.

At other times during August and September a number of watermelons were cut open in the fields and left to ferment and decay. At no time did these attract any bollworm moths, although the cotton moth *Alabama* (*Aletia*) *argillacea* was observed to feed on them to a slight extent.

Experiments were also tried by spraying the cowpea vines with a mixture of sorghum, vinegar, and beer poisoned with cobalt. This

[a] Bul. La. Expt. Sta., 2 ser., 48, p. 155.

[b] Bul. No. 30, n. s., Div. Ent., U. S. Dept. Agric., p. 86.

injured the vines to a slight extent, but no moths could be seen feeding on it, nor could dead ones be discovered in the vicinity.

From these tests it is safe to conclude that the use of poisoned sweets can never be a success in trapping the moths.

LENGTH OF LIFE CYCLE.

The duration of the embryonic, larval, and pupal instars has already been discussed, and the length of the life cycle is easily had by combining these records made on the same individuals.

This has been done in the following table, which gives the duration of a series of life cycles during the different parts of the season of 1904, at Paris, Tex.

TABLE XXXVIII.—*Length of life cycle at Paris, Tex., 1904.*

Eggs laid.	Eggs hatched.	Larvæ pupated.	Moth emerged.	Life cycle.	Sum of effective temperatures.
				Days.	*° F.*
April 2	April 10	May 8	May 31	59	1,485
April 12	April 19	May 16	June 3	52	1,420
April 29	May 5	June 3	June 20	53	1,601
July 6	July 9	July 27	August 16	41	1,597
July 16	July 19	August 2	August 17	32	1,237
August 5	August 8	August 22	September 4	30	1,186
Do	do	August 25	September 11	36	1,573
August 28	August 31	September 27	October 15	48	1,319
September 5	September 8	September 24	October 10	35	1,138
September 13	September 16	October 10	November 15	63	
Average					1,417

At Victoria, the previous season, some life-cycle records were made early in the year, averaging as follows:

TABLE XXXIX.—*Length of life cycle at Victoria, Tex., 1903.*

Eggs laid.	Eggs hatched.	Larvæ pupated.	Moth emerged.	Life cycle.
				Days.
April 14	April 18	May 16	June 2	49
May 3	May 6	May 28	June 14	42

The influence of the seasonal variation in temperature is very plainly to be seen, the length of the life cycle decreasing from fifty-nine days early in the spring to only thirty days during the hottest part of the summer.

It will be noted that the sums of effective temperatures for the different records vary from 1,186° to 1,601°, with an average of 1,417° F. This latter may, no doubt, be accepted as very near the normal at moderate summer temperatures.

GENERATIONS OF THE BOLLWORM.

It has long been stated that the number of generations annually of the bollworm in the cotton belt varies from about four in the more northern part to six or even seven in the extreme southern part. It does not appear, however, that this statement is based on actual breeding experiments, but rather on the result of field observations. Conclusions regarding this matter based solely on field observations are somewhat unsatisfactory, as they are apt to be spread over a wide territory and to be complicated by variations in climate and environment, as well as by the fact that the broods are confused on account of the long period of emergence of the moths in the spring. This causes the period of spring oviposition to be lengthened, so that long after the majority of bollworms are well grown others are still in the egg stage. These supplementary generations persist throughout the season, and, although numerically unimportant, are apt to lead to confusion regarding the principal ones.

As the question of the number of generations is one of importance, effort has been made to secure as much data on the subject, confirmatory or otherwise, as possible. In 1903 attempt was made to secure information on this point by ascertaining, for different localities of the cotton belt, the periods of maximum oviposition of the moths during the season. It was thought that these egg records for the season, when plotted, would indicate approximately the periods of greatest abundance of the moths, thus marking the respective generations. Theoretically such data would undoubtedly furnish the information desired, but in practice many factors were found to enter into the making of trustworthy records, such as variations in the age of the corn used in making counts, the character of the weather, etc., so that little may be safely inferred from the egg records obtained. It is proper, however, that acknowledgment be here made of the assistance received in this work from Dr. W. R. Shaw and Mr. A. C. Lewis, of the Oklahoma Agricultural Experiment Station; Mr. Mark Riegel, Pomona, Ga.; Prof. H. A. Gossard, of the Florida Agricultural Experiment Station, and the late Mr. G. H. Harris, of this Department. The records made by Mr. Riegel and by Mr. Harris are presented under the caption "Oviposition on corn" (p. 42), to which the reader is referred.

At the beginning of the season of 1904 it was decided to carry a series of consecutive generations through the entire summer under natural field conditions. This work was conducted in a large field cage placed in a lot adjoining the laboratory at Paris, Tex. The cage consisted of a solid framework 15 feet long, 12 feet wide, and 8 feet high, covered with ordinary black window screen and provided with a small door on the side. (See Pl. XVII.) In it were planted two lots

of corn, March 2 and May 5, and two lots of cotton, April 29 and July 26. With this arrangement the corn could be cut when it was no longer needed and the entire space given up to cotton later in the season. The screen prevented the escape of any moths or larvæ, but left them subjected to very nearly normal weather conditions. It also served to keep out predaceous enemies and many of the larger parasites, thus providing against possible depletion from these sources, and at the same time preventing access to the plants by moths outside of the cage.

The cage was stocked with a large number of eggs on May 9, and the forthcoming generation of bollworms was traced in its development. The following table, compiled from daily records, summarizes very briefly the average growth of each generation:

TABLE XL.—*Generations of bollworms, Paris, Tex., 1904.*

[Dates are for Paris, Tex., latitude about 33° 45′.]

Brood.	Moths out.	Eggs deposited.	Larvæ hatched.	Larvæ one-fourth grown.	Larvæ one-half grown.	Larvæ three-fourths grown.	Larvæ full grown.	Pupæ.
1 (50 days).	May 6	May 9	May 14	May 21	May 26	June 1	June 5	June 8.
2 (35 days).	June 25	June 27	June 30	July 7	July 11	July 14	July 16	July 18.
3 (31 days).	Aug. 3	Aug. 5	Aug. 7	Aug. 10	Aug. 14	Aug. 17	Aug. 20	Aug. 22.
4 (48 days).	Sept. 3	Sept. 10	Sept. 13	Sept. 18	Sept. 23	Sept. 25	Sept. 27	Oct. 2; in hibernation.
5	Oct. 22							

The first record of injury to cotton was on July 6, due to young larvæ of the second brood. The damage rapidly increased until, on July 12, some sixty squares and a few young bolls had been destroyed. A few days later, after the larvæ from corn had pupated, the corn was removed and late cotton planted in its place. The injury of the two following generations was confined entirely to the early planted cotton, as the late cotton was not squaring in time to be subject to attack. The fourth brood was represented by but few individuals, due possibly to the fact that the greater number of the pupæ from the third generation had remained in the soil to hibernate. This conclusion was strengthened by the appearance of a moth on September 22, evidently a belated specimen of the generation due to emerge on September 3. The few larvæ pupating early in October also passed into hibernation with the pupæ of the previous generation still in the soil.

LABORATORY EXPERIMENTS.

In working out the life cycle of the bollworm in the laboratory at different times during the summer it was found by Mr. Girault that the growth and transformations undergone by individuals indoors closely coincided with the data obtained from the field work. The two sets of experiments were run along together, and the agreement

between the two was most gratifying. His laboratory records are presented in connection with the lengths of the life cycle on page 97.

From observations and breeding experiments there can be no doubt that there are four principal generations each season in northern Texas. Besides these there is a fifth, which is of very small extent, and appears too late to damage cotton to an appreciable extent.

At Victoria, Tex., about 320 miles south of Paris and in about the latitude of Leesburg, Fla., the number of annual generations, from all available data, appears to be about six. On the basis of four broods at Paris, six broods at Victoria could reasonably be expected by reason of its more southern location and consequent longer breeding season. In 1903, and also in 1904, moths were out and ovipositing freely by the 1st of April, and in the fall of the former year, essentially normal, larvæ had largely entered the soil for hibernation as pupæ by the middle of November. There would thus be a breeding period of 234 days, time sufficient for six broods at the average time of 37 days for each generation and a few days over, indicating a partial seventh generation, which actually occurs by the emergence of a few moths from late fall pupæ.

It is considered very probable that in the vicinity of Brownsville, Tex., and extreme southern Florida there may be seven full generations each year. In the vicinity of Miami, Fla., according to Prof. P. H. Rolfs, complete hibernation probably does not occur, as he has observed bollworm larvæ during the winter months feeding on tomatoes, naturally necessitating more or less activity on the part of the moths during this period. However, according to the gentleman mentioned, the larvæ do not appear in force until along toward May, so it would appear that the bulk of the insects hibernate as pupæ.

It is therefore seen that there may be from four to six annual generations of the bollworm for the cotton belt. It will be remembered that this number agrees exactly with the estimated numbers of generations by other workers. For the extreme southern parts of the United Stated complete hibernation may or may not occur, depending on local conditions and the character of the season.

The number of annual generations of the bollworm has been indicated with more or less certainty for several localities in the central and more northern States.

For northern Delaware, Professor Sanderson states:[a]

> In this latitude the moths appear during May and deposit their eggs on corn and other food plants, such as beans. * * * The second brood of moths appears in northern Delaware about the middle of July, and a third brood during the first two weeks of September. This would indicate three generations of larvæ, the third pupating for the winter.

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[a] Insects injurious to staple crops, 1902, p. 153.

In New Jersey, according to Dr. J. B. Smith,[a] moths appear early in May and long before there is any corn for them to oviposit on. Eggs are therefore deposited on a great variety of plants, peas and tomatoes being favorites. Toward the end of May early corn is well up, aud some eggs are deposited on these plants, the larvæ eating in the buds and often boring into the stems. By the middle and toward the end of June the earliest larvæ are full-grown on peas and are ready for pupation. By the middle of July most of the larvæ on tomatoes in the southern part of the State are full grown and before the end of the month have disappeared. At this time, before the middle of July, moths from the earliest larvæ have appeared and have laid their eggs on corn. Young larvæ are found on the small ears before July 20, and by the middle of August have attained their growth and have changed to pupæ. The pupal stage at this time lasts only about a week and young larvæ of a third brood appear before the 1st of September. There may thus be three broods of this insect in the southern part of the State. North of the Sandy Plain two broods are normal and a third is very exceptional.

Concerning the number of generations in Ohio, Webster and Mally state:[b]

> While there may be three broods in southern Ohio, in the northern part of the State there are probably but two. These broods appear to be interminably mixed before fall, and so late as November partly grown larvæ may be found in the ears of corn.

Three generations are indicated for Illinois by Mr. C. A. Hart,[c] in spring boring into tomatoes, in summer eating unfolding corn, and later feeding in the cavity near the tip of the growing ear.

According to Professor Osborn,[d] in Iowa—

> There are probably two broods in this latitude. The larvæ of the first brood appear in the early part of the season and feed on various plants, so that they do not attract attention, while the second brood of larvæ attacks the corn at the time the ears are forming or soon after in the manner already described. The second brood of larvæ pupate and produce moths in the latter part of the summer, and farther south at least it is stated that a third brood of larvæ occurs from which pupæ are produced to pass the winter.

A statement by Professor Riley[e] in the Fourth Report is of interest in this connection:

> If, as we have stated, there are 3 normal broods a year as far north as New Jersey, Ohio, and northern Illinois, then in South Carolina, north Georgia, Tennessee, and Arkansas there are probably 4 broods, and as many as 6 in south Texas and Florida.

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[a] Ann. Rep. N. J. Exp. Station, 1892, p. 442.
[b] Bull. 96, Ohio Agric. Exp. Sta., p. 17.
[c] Syn. Ins. Coll. for Ill. High Schools, 1903, p. 38.
[d] Bull. 24, Iowa Agric. Exp. Sta., p. 1004.
[e] Fourth Rept. U. S. Ent. Com., p. 373.

In Massachusetts, according to Lounsbury[a]—

The caterpillars pupate beneath the surface of the ground, and those of the second brood pass the winter in the pupal stage.

Concerning the generations of this insect in Ontario, Prof. W. Lochhead states:[b]

Observations point to the view that the corn worm is single-brooded with us, but it may be double-brooded in some of the southern localities.

In order to ascertain, if possible, what relation the total effective temperature during the breeding season has to the number of generations of the bollworm in different localities, the following table was constructed. It is based on Weather Bureau temperature records for various localities and the effective temperature determinations derived from laboratory experiments at Paris, Tex. In each case it is assumed that the average effective temperature required for a single life cycle is 1,417° F. and that activity in the spring does not begin until the monthly mean has reached from 62° to 65°, ceasing in the fall at the same temperature. Such assumptions seem justified by the observations presented in the earlier part of this bulletin.

TABLE XLI.—*Effective temperatures, calculated and reported number of generations of bollworm for different parts of United States.*

Locality.	Season of activity.	Total effective temperature during season of activity.	Calculated number of generations.	Reported number of generations.
		° *F.*		
Jupiter, Fla	All year	11,058	7.9	
Victoria, Tex	Mar. 1–Nov. 30	8,876	6.2	6.
Paris, Tex	Apr. 1–Oct. 31	6,802	4.2	4.
Baltimore, Md	May 1–Sept. 30	4,362	3.0	3 (Delaware).
Indianapolis, Ind	do	4,178	2.9	2–3 (Ohio).
Boston, Mass	June 1–Sept. 30	2,967	2.1	2 (Mass).
Oswego, N. Y	June 1–Aug. 30	2,217	1.5	1–2 (Ontario).

SEASONAL HISTORY.

APPEARANCE OF SPRING MOTHS.

The earliest records of moths in various parts of Texas during the spring of 1904 have been already referred to in connection with oviposition, where the dates of finding the first eggs are given. While these dates probably represent very nearly the first emergence of moths, they do not show the general appearance, which is much later. Thus, the first moth to emerge at Victoria from a lot of overwintered pupæ appeared March 20, and the last April 18, nearly a month later, while at Paris the moths first appeared during April, the greater portion not until the middle of May, and the last not until well on toward the

[a] Bul. 28, Mass. Agric. Exp. Sta. (Hatch), p. 16.

[b] Rept. Ent. Soc. Ontario, 1901, p. 75.

beginning of June. The later broods also showed long periods of emergence, as indicated below.

TABLE XLII.—*Dates of emergence of moths.*

Generation.	Paris, 1904.	Calvert, 1903.
First	April 3 to May 30	April 5 to June 5.
Second	June 20 to July 10	June 20 to July 5.
Third	July 18 to August 22	July 20 to August 20.
Fourth	August 25 to September 25	August 25 to September 20.
Fifth	October 1 to October 5	(?)

It must be understood that these dates are the result of general impressions and observations made on oviposition, larvæ, etc., and can not be put forth as exact data.

It was thought at first that there might be some very definite relation between the sum of effective temperatures to which the pupæ had been subjected during the winter and spring, and the dates of spring emergence; but calculations based on Weather Bureau temperature records do not show this. The dates of appearance in the different parts of the State are much closer together than such figures would indicate. It seems, rather, that spring emergence must be determined by the temperature of the soil during a smaller number of consecutive warm days. Our Texas records tend to show that moths begin to come out in the spring about the time that the mean monthly temperature reaches 63° to 65° F.

PROGRESS OF INFESTATION BY GENERATIONS.

Once the spring moths are out they soon begin to oviposit, principally on young field corn, it being the most general food plant for the first generation of larvæ. These larvæ mature in the corn, pupate, and the moths of the second generation emerge in time to oviposit upon the tassels and young ears of the corn in the same fields which supplied food for the first generation. The resulting larvæ mature, most of them pupating just as the ears commence to harden. Two weeks later, when the third generation of moths appears, the early corn is well hardened and unfit for oviposition. On this account the near-by cotton fields are chosen by the moths and the eggs of this generation are placed on the cotton plants. The larvæ of this generation also attack late corn if it is accessible, much preferring it to cotton. This is the generation of bollworms which does the greater part of the injury to cotton. Alfalfa is also considerably attacked by this generation, even if it is growing close to corn and cotton. The fourth generation, appearing early in September, attacks especially late cotton, which is still green and bearing squares and young bolls. Late corn and alfalfa also suffer to a considerable extent from this generation.

INCREASE IN NUMBERS DURING THE SEASON.

The comparative difference in numbers between the moths of the first and second generations can be determined in a general way from the tables on oviposition already given, since corn receives practically all the eggs of these generations. It is seen that the second generation lays about forty times as many eggs as the first, and assuming, as seems to be the case, that these moths lay individually many more than the spring moths, it may be said that for every spring moth there are thirty moths in the second generation. This agrees well with observations made in the field.

Fifteen, or one-half of these moths being females, lay probably about 1,100 eggs each. Of these only about one larva in fifteen matures, or about fifteen times as many as there were moths in the second generation. This number is about 1,100.

Half of these, emerging as female moths of the next generation, will lay in all some 605,000 eggs. Observations show that about one in ten of these eggs, or 60,500, will give rise to destructive larvæ.

Allowing for the probable decimation of 65 per cent by the parasites and predaceous enemies of the growing bollworms, there still remain some 21,175 larvæ of the third generation to mature on cotton for every moth emerging the previous spring.

This shows the great importance of destroying the larvæ of the first generation, as every one of them will average 683 descendants in the late summer capable of completely ruining 78 large cotton plants.

DO THE ADULTS HIBERNATE?

The hibernation of the adult bollworm moth has always been an open question, and in order to obtain all possible data bearing evidence on this point, Mr. Girault made a trip into southern Texas during the early part of February, 1904, with the especial purpose of searching for hibernating individuals.

At Corpus Christi and Victoria a number of days were spent in examining places where hibernating moths would be apt to hide. These included woodlands surrounding fields, rubbish in corn and cotton fields, barns, outhouses, etc., but not a single bollworm moth was discovered. Fresh growing plants and garden vegetables were searched also and sugaring tried, but with the same result.

Mr. J. D. Mitchell, of Victoria, believed that he had frequently seen hibernating specimens, but in two cases at least it was found that he had been misled by the close resemblance in color and general appearance of *Heliophila* (*Leucania*) *unipuncta* Haw. and *Remigia repanda* Fab., to the bollworm moth.

All laboratory experiments bearing on this point also tend to show that while life may be prolonged by subjection to low temperatures, no

INSECTS SOMETIMES MISTAKEN FOR THE BOLLWORM.

Fig. 1, Cotton square attacked by caterpillar of *Calycopis cecrops;* fig. 2, larva of *Prodenia ornithogalli*, injurious to cotton square; fig. 3, larger larva of same species, boring into a large boll; fig. 4, adult moths of the same—all figures enlarged about one-half (original).

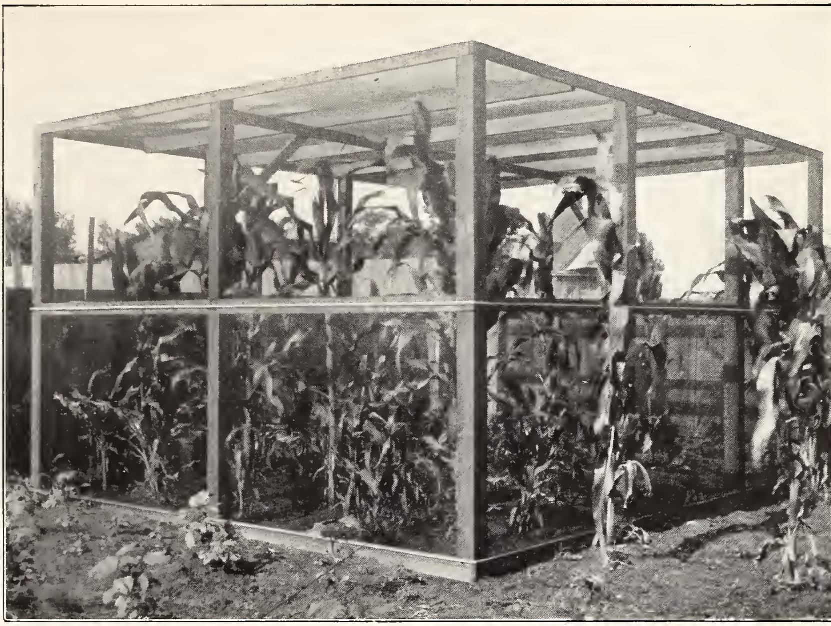


FIG. 1.—LARGE BREEDING CAGE.

Used at the Paris laboratory in determining generations of the bollworm. Planted to corn (original).

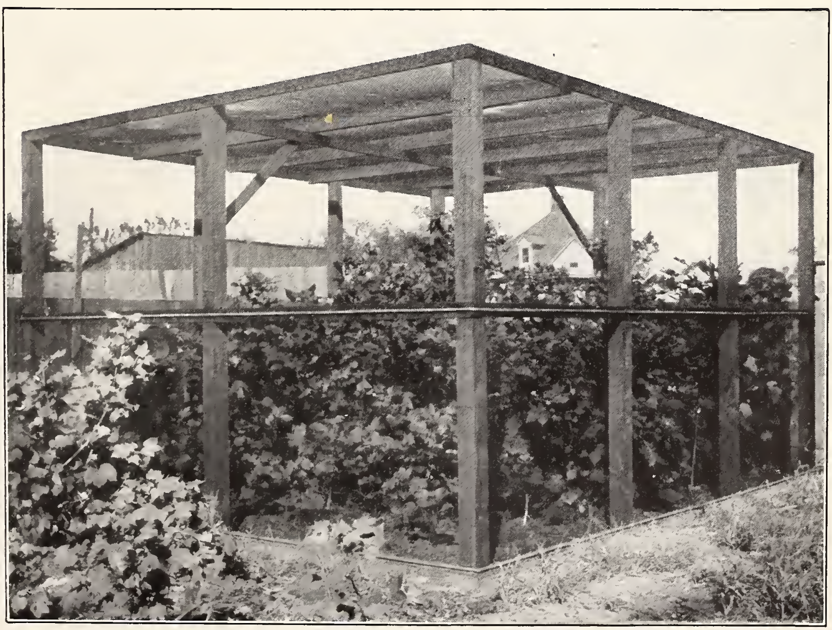
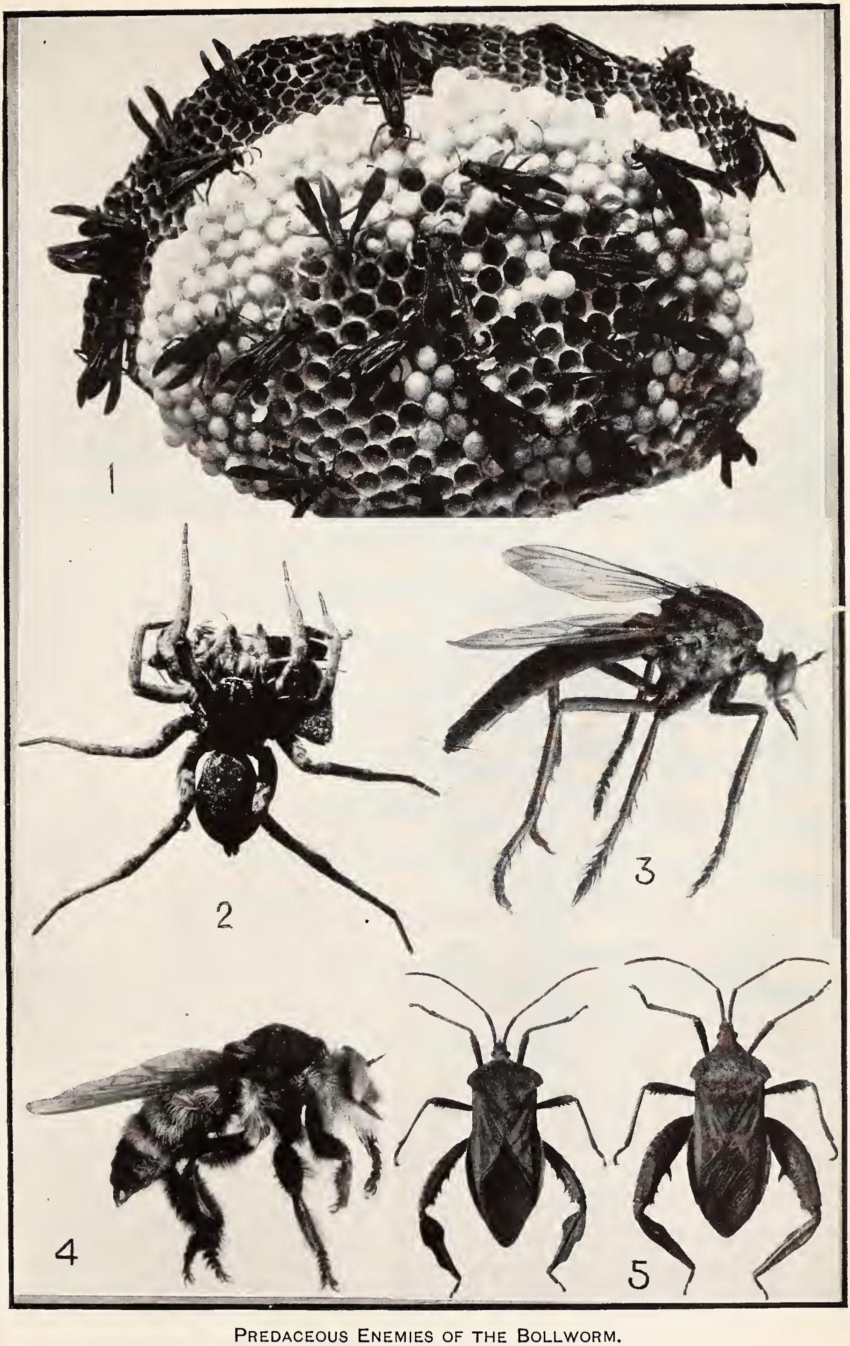


FIG. 2.—SAME, PLANTED TO COTTON LATER IN THE SEASON (ORIGINAL).



PREDACEOUS ENEMIES OF THE BOLLWORM.

Fig. 1, *Polistes annularis*, a wasp predatory on the bollworm, and its nest, two-thirds natural size; fig. 2, *Lycosa riparia* with captured bollworm moth, natural size; fig. 3, *Deromyia angustipennis*, a robber fly predatory on the bollworm moth, enlarged one-half; fig. 4, *Mallophora orcina*, another robber fly which destroys moths, enlarged one-half; fig. 5, *Metapodius femoratus*, ♂ ♀, known to attack bollworms, enlarged one-half (original).

moths live long enough thus to enable them to pass the entire winter in hibernation.

With regard to the moths in the large field breeding cages some evidence was secured. Although scattering moths continued to emerge during September and October, all died within a short time, and none showed the slightest inclination to hibernate.

This is, of course, negative evidence, but enough to permit of the conclusion that hibernation of the moths in Texas is most unlikely, and that if it does occur an extremely small number must hibernate in this way compared with the numbers of the insect which pass the winter in the pupal stage.

On the other hand, it is quite probable that in southern Florida the moths remain more or less active throughout the entire year, since the temperature there ordinarily does not fall below 65° F. in the winter. This is not true hibernation, however.

INSECTS SOMETIMES MISTAKEN FOR THE BOLLWORM.

Unlike the Mexican boll weevil, the bollworm has been for so long a well known cotton pest that it is rather unusual for planters to confuse it with any other insect affecting cotton.

There are, however, two other caterpillars which injure cotton in exactly the same manner as the bollworm, so that unless the insects themselves are in evidence it is not possible to tell their work from that of the genuine bollworm. Fortunately neither of them is ever present in large numbers, and the damage which they cause is immaterial compared to that done by the bollworm.

The first of these is the cotton cutworm, *Prodenia ornithogalli* Guen. (see Pl. XVI, figs. 2, 3, 4), which sometimes feeds on the squares, flowers, and bolls. It bores into them in exactly the same way as the bollworm. It is also a very general feeder, frequently occurring on the spiny pigweed growing adjacent to cotton. Larvæ were seen on cotton only during July and the early part of August, disappearing after that date.

The second is the larva of a butterfly, *Calycopis cecrops* Fab., better known under the name of *Thecla pœas* Hbn. The adult oviposits on the involucre surrounding the squares, and the resulting larvæ eat out the contents of the squares, making a large hole in the side similar to that left by a good-sized bollworm (see Pl. XVI, fig. 1). This caterpillar also is most abundant early in the season, generally during the latter half of June and the first two weeks in July. No doubt it would be much more destructive were it not for the frequency with which parasites prey upon it. Out of eight or ten larvæ brought into the laboratory at various times every one proved to be parasitized.

As has been mentioned already, the work of the young bollworm is often termed "sharpshooter work," and the very young larvæ referred to as sharpshooters, thus confusing them with the true sharpshooter, *Homalodisca triquetra* Fab., which feeds by puncturing the stems of the cotton plant (see fig. 12).

When greatly pressed for food, the cotton-leaf caterpillar, *Alabama* (*Aletia*) *argillacea*, sometimes injures small bolls in a way which might possibly be mistaken for bollworm injury. Bolls thus injured always have the involucre eaten away first, and then large irregular cavities are eaten out along the sides. Often several caterpillars take part in injuring the same boll.

In the identification of the bollworm moth by planters frequent mistakes are made. The moths most usually confused are the army worm, *Heliophila* (*Leucania*) *unipuncta*, and the cotton moth, Alabama, just referred to above. It is very unfortunate that such confusion exists, since on account of it the moths of the third brood are not noticed when they begin to oviposit on cotton. To know the dates of maximum oviposition is important, since all attempts at poisoning the young larvæ must be made with a knowledge of the time when they will be hatching from the eggs.

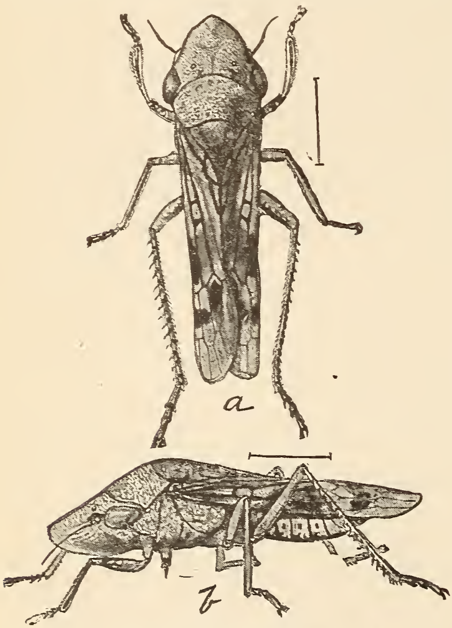


Fig. 12.—"Sharpshooter," *Homalodisca triquctra* (after Riley and Howard).

On corn, however, several species injure the plant in a way somewhat similar to the bollworm, both by feeding in the tender "bud" and in the ear. In the South the larva of the fall army worm, *Laphygma frugiperda* S. & A., is often found during the spring of the year eating out the bud of field corn, and from its resemblance to the lighter-colored bollworms is usually mistaken for that insect. During the summer late-planted June or other corn is usually badly infested by the fall army worm, and the offender is almost universally considered to be the bollworm. The former insect occasionally bores into the soft milky ears of corn, either from the tip end, or from the base or side.

In the more northern States, and occasionally south, the larva of *Papaipema nitela* Guen. eats into the bud of young field corn, boring

down into the stem, and its work is thus likely to be confused with that of the bollworm. Various cutworms at times attack corn in a way which, in the absence of the culprit, would suggest bollworm injury.

PREDACEOUS ENEMIES.

PREDACEOUS ENEMIES OF THE EGGS AND YOUNG LARVÆ.

The exposed position in which the eggs are placed lays them open to attack by numerous insect enemies, although the fact that they are scattered promiscuously about on the plants no doubt prevents much wholesale destruction which might otherwise take place.

The nymphs and adults of *Triphleps insidiosus* Say (see fig. 13) have been repeatedly observed feeding on bollworm eggs and on very small larvæ. This little heteropteron is especially abundant in fresh corn silk, and is often seen frequenting cotton plants also. Although in a number of instances noticed in the laboratory they seem loath to attack living larvæ, they are sometimes to be seen in the field with newly hatched larvæ impaled on their slender beaks. Their principal value lies, however, in the large number of eggs which they destroy. A special count was made at Sulphur Springs, Tex., on August 16, 1904, to determine the probable proportion of eggs destroyed by this agency. The eggs on ten different silking ears were examined, and on an average 55 per cent of the eggs were found to be shriveled. It is probable that most of these shriveled eggs had been punctured and their contents sucked out by the Triphleps, which were numerous on the silks at that time. This is no doubt an exceptional case, but it serves to show of what great value the Triphleps may be under favorable conditions.

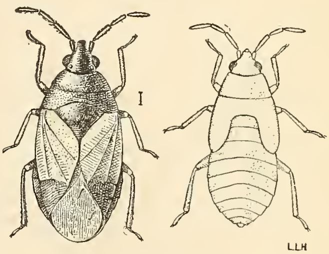


FIG. 13.—*Triphleps insidiosus:* adult and nymph (original).

Larvæ of the coccinellid beetle *Megilla maculata* DeG., were observed on several occasions feeding upon bollworm eggs, and they probably do so very generally, especially on corn, where Megilla is quite abundant. In feeding they often tear the egg from its support, eat out the contents, and cast aside the empty shell. The ladybird larvæ can not cope with bollworms which are their equal in size, but no doubt often feed upon those newly hatched if eggs are scarce. While no other species were observed to feed on bollworm eggs or larvæ, it is not improbable that others do. Figure 14 illustrates a common form in cotton fields, feeding on plant lice and possibly on other insects.

Ashmead[a] records an ant, *Monomorium carbonarium* Smith, as feeding on the bollworm, and the same ant was again seen at Victoria feeding on embryo bollworms extracted from their shells. The same observer found *Solenopsis geminata* Fab. eating bollworm eggs, and we have seen

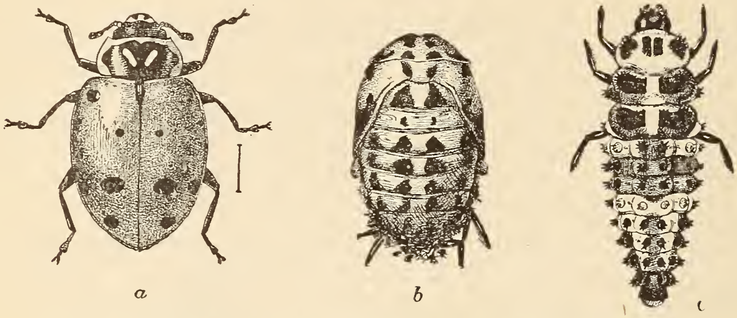


FIG. 14.—*Hippodamia convergens:* adult, larva, and pupa (from Chittenden).

a second, smaller species of the genus (*Solenopsis texana* Em.) very common on young cotton plants and apparently destroying newly hatched larvæ which had been placed there purposely. Other ants have been observed under more or less suspicious circumstances which point to them as possible bollworm destroyers, although, on the whole, their value in an economic way is very doubtful. Following is a list of the ants in the probable order of their importance:

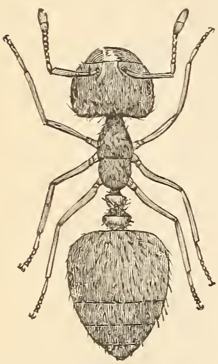


FIG. 15.—*Solenopsis geminata* (after McCook).

1. *Solenopsis geminata* Fab.
2. *Cremastogaster lineolata* Say.
3. *Solenopsis texana* Emery.
4. *Monomorium carbonarium* Smith.
5. *Dorymyrmex pyramicus* Smith.
6. *Forelius maccooki* Emery.

A worker belonging to the first of these species is shown in figure 15.

The larvæ of certain species of Chrysopa (fig. 16) are often abundant on corn and cotton plants, feeding on both the young larvæ and the eggs. The eggs of the chrysopa are laid on the cotton plants quite frequently and are sometimes mistaken for the eggs of the bollworm. They are deposited in an entirely different manner, however (see fig. 16, *a*), being attached by a long flexible stalk and not laid flat upon the plant, as is the case with those of the bollworm.

On two occasions, once at Clarksville, Tex., and again at Victoria, during May, 1903, a small reddish mite was seen feeding on freshly laid bollworm eggs.

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[a] In Insect Life, 1894.

PREDACEOUS ENEMIES OF THE LARGER LARVÆ AND MOTHS.

Foremost among the predaceous enemies of the bollworm are several species of Polistes. There are three species which frequent the cotton fields: *P. annularis* Linn., a large black form with black wings and a single black cross band of yellow near the base of the abdomen; *P. rubiginosus* Lepel., a large, slightly stouter, rust-red species, with dark wings; and *P. texanus* Cress., a smaller, more slender, and variably striped form with paler wings. *Polistes annularis* builds large nests, often nearly a foot in diameter (see Pl. XVIII, fig. 1), and sometimes containing upward of a thousand cells; the others construct smaller nests, generally from 3 to 6 inches in diameter, and containing a proportionately smaller number of cells.

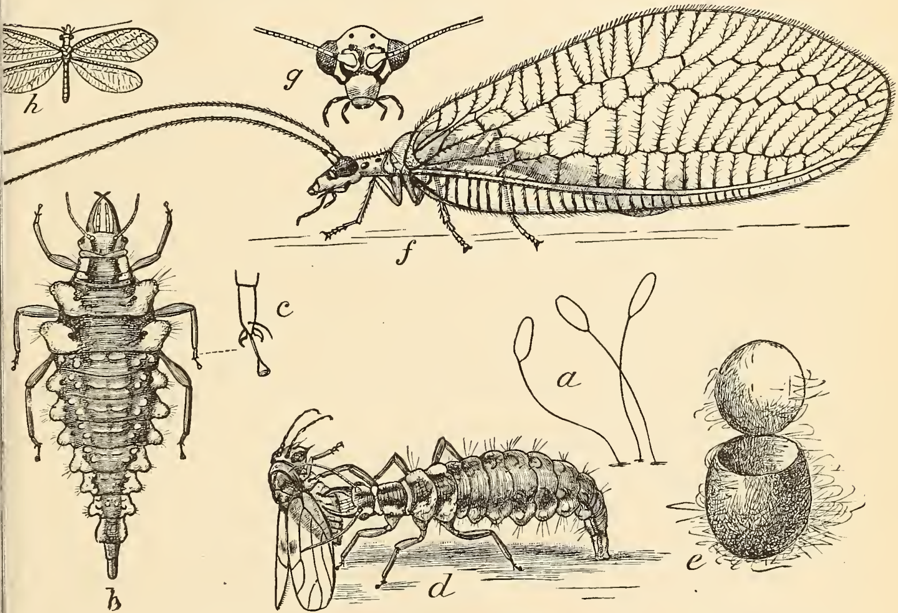

FIG. 16.—*Chrysopa oculata:* adults, eggs, larvæ, and cocoon (from Marlatt).

The adults of Polistes pass the winter hibernating in protected places near the cotton fields, and early in the spring each female starts a new nest. The larvæ of the wasps are fed upon chewed-up bits of caterpillars captured by the wasps. By the middle of the summer, when the bollworm is attacking cotton, their colonies are well grown and vast numbers of the wasps are circulating through the cotton fields in their tireless search for caterpillars. Once a bollworm is discovered, the Polistes seizes it just back of the head with her mandibles and in the case of a large worm usually stings it to death. Then, after a preliminary chewing, she carries it off to the nest, where it is distributed and fed to the wasp grubs. All cotton fields are well supplied with the wasps,

which build their nests in nearby trees or sheds close to their foraging ground. The prickly branches of the osage orange trees, which often grow along the roadsides, are favorite locations for them.

It is difficult to estimate the amount of good done by the wasps, but there can be no doubt that it is very considerable, probably exceeding that done by any other of the predaceous enemies. They are at work from daylight until dark, constantly in search of larvæ, and the vast numbers foraging in the cotton fields must necessarily destroy the bollworm almost exclusively. The most abundant and undoubtedly the most beneficial form is *Polistes annularis*.

On one occasion a nest of *P. annularis* at Pittsburg, Tex., was watched by Mr. Bishopp to ascertain the number of bollworms brought in by the wasps. The nest was of medium size, consisting of about twenty-five or thirty cells, with pupæ, 200 to 250 larvæ, and 30 adults present at one time on the nest. During a period of half an hour eight bollworms and one Geometrid caterpillar were brought in by the wasps and fed to their larvæ and to other adults.

From these facts it is apparent that the present custom of wantonly destroying the nests of these wasps where they occur in or about cotton fields is a bad practice and should be disparaged strongly, so that the wasps may have full sway in their beneficial work.

The wasps also frequent corn fields, and we have often watched them searching for bollworms where we have passed along the rows stripping the shucks from the ears and removing the larvæ. Several times they were seen to pounce upon larvæ left intentionally upon the ears. In cotton fields, where the larvæ are most exposed, the wasps are continually in search for them, feeding by turns on the honey secreted by the nectaries on the squares.

Forming another group of predaceous enemies are a few large species of robber flies (Asilidæ) which frequent the fields. These flies do not destroy the larvæ, but confine their attacks solely to the moths. The only species actually seen with a bollworm moth was the large brown *Deromyia angustipennis* Loew, but judging from their observed habits the numerous Erax and Mallophora (Pl. XVIII, figs. 3 and 4) must undoubtedly catch the moths also. On one occasion a specimen of Deromyia was brought into the laboratory and tested as to its feeding habits. A bollworm moth was introduced into the jar with the fly, and although the latter was much hampered by lack of freedom, scarcely two seconds elapsed before it had secured the fluttering moth firmly between its legs and was inserting its sword-like proboscis into the moth's body. The following is a list of the more common robber flies which were observed in the cotton fields:

Erax lateralis Macq.
Erax bastardii Macq.
Mallophora orcina Wied.
Deromyia angustipennis Loew.
Deromyia umbrinus Loew.
Dizonias bicinctus Loew.
Scleropogon latipennis Loew.

Another enemy of some interest, although probably of small importance, is the wasp *Eumenes bollii* Cress. On one occasion a nest of this species was found by Mr. Bishopp on a cotton leaf at Ladonia, Tex. The nests are constructed of mud and stored with caterpillars as food for the young wasp grub, which matures inside the clay nest. There can hardly be any reasonable doubt that the wasp building in this situation made use of bollworms for storing its nest.

Quite a number of spiders were observed at various times destroying the bollworm in its different stages. In three of these cases moths had been captured, once at Victoria by a large specimen of *Lycosa riparia* Hentz (Pl. XVIII, fig. 2), and again at Paris, Tex., and also at Ladonia by a jumping spider (*Attus fasciolatus* Hentz). A specimen of the same species of *Lycosa*, which was kept in captivity during the summer, proved to be very fond of bollworm larvæ and moths, devouring several during the course of a day.

A small striped Attid spider (*Dendryphantes nubilis* Hentz) was not infrequently seen nesting beneath the involucres of the cotton squares at Paris, and on three different occasions they were observed with one-eighth to one-fourth grown larvæ which they had captured in these situations. Another form (*Attus cardinalis* Hentz) was seen at Calvert, Tex., during August, 1903, with a half-grown bollworm in its jaws.

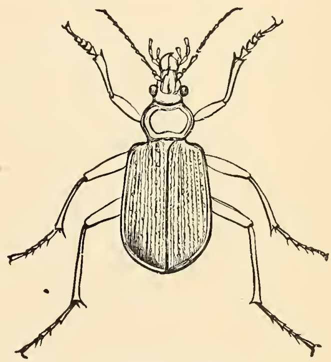

FIG. 17.—*Calosoma scrutator:* beetle (after Comstock).

No Texas ants have been observed in the act of capturing any large larvæ or moths, and it is probable that none of them do so, except under very exceptional conditions. Several times larvæ which had most probably been previously injured were being devoured by ants, and once a moth which had emerged under a jar in the garden was found dead soon afterward, literally covered with the little yellow "thief ant," *Solenopsis texana* Em. That they were the cause of its death is, however, exceedingly doubtful.

Among the beetles there are two groups which probably destroy a fair number of bollworms. Certain ground beetles, notably *Calosoma angulatum* Chev., *C. scrutator* Fab. (fig. 17), *C. calidum* Fab. (fig. 18), and *Harpalus caliginosus* Fab., all known to have a fondness for caterpillars, are not infrequent in cotton fields and are probably of some

service. Several species of tiger beetles are also common. Their larvæ nest in burrows in the soil about the plants, no doubt destroying an occasional larva, which for some reason or another finds itself upon the ground. The most abundant of these are *Tetracha carolina* Linn. and *Cicindela vulgaris* Say.

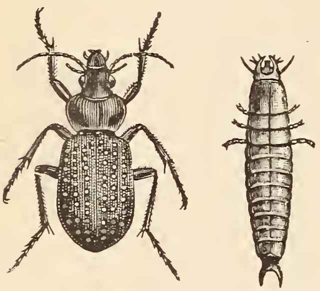

FIG. 18.—*Calosoma calidum:* beetle and larva (from Riley).

Several large predaceous Hemiptera known to destroy caterpillars are often seen in cotton fields, but none of them have actually been seen by us in the act of devouring a bollworm. The following list includes the more important members of this group:

Metapodius femoratus Fab. (Pl. XVIII, fig. 5).
Sinea diadema Fab.
Melanolestes picipes H.-Sch.
Apiomerus crassipes Fab.
Arilus cristatus Linn.
Podisus spinosus Dall. (fig. 19).
Œbalus pugnax Fab.

In addition to the aforementioned enemies, the "devil's horse" (*Stagmomantis carolina* Burm.) may be mentioned as an actively predaceous insect frequenting the fields.

Among the vertebrate enemies, the common toad (*Bufo lentiginosus* and *B. valiceps*) stands out as rather important. Although feeding upon almost any living insects which it can capture, sometimes at least bollworms form a considerable portion of its diet. On September 14, 1904, Mr. C. R. Jones collected at Germantown, Ark., a number of toads from a field of late cotton badly infested by the bollworm. The toads in the field at that time were exceedingly numerous, and nine were sent in for dissection, with the following results:

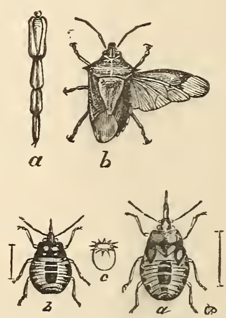

FIG. 19.—*Podisus spinosus:* adult, egg, and nymphs (from Riley).

TABLE XLIII.—*Stomach contents of toads from cotton field at Germantown, Ark., September 14, 1904.*

Toad.	Number of bollworms.	Miscellaneous insects.
No. 1...	None	Small ant; Aletia larva, ¾-inch.
No. 2...	....do	Aletia larva, 1-inch; two ladybirds; a Sciara; a small Chrysomelid beetle.
No. 3...	Two: ¾-inch and ¼-inch	Chrysopa larva, Scydmænid, and Chrysomelid.
No. 4...	None	Aletia larva, ½-inch, and a small Carabid.
No. 5...	....do	Aletia larva, full grown; a few small Coleoptera.
No. 6...	Four: Full grown, 1⅛-inch, ⅔-inch, piece of large worm.	None.
No. 7...	One: ¾-inch	Do.
No. 8...	Two: ¾-inch and ¼-inch	Miscellaneous bits.
No. 9...	One: ½-inch	Several small Coleoptera.

The toads examined were from 1½ to 2 inches in length, and no doubt larger specimens would have had even larger capacities for bollworms.

Another lot of toads, collected at Calvert, Tex., on the night of August 13, 1903, gave the following large number of bollworms, besides some other caterpillars and a few beetles:

Table XLIV.—*Stomach contents of toads from cotton field at Calvert, Tex., August 13, 1903.*

Toad.	Bollworms in stomach.
No. 1..	23, mostly large.
No. 2..	21, all rather large.
No. 3..	3, all large.

On another occasion a large toad was brought into the laboratory and fed on bollworms. It devoured six large bollworms within half an hour, two moths within the next ten minutes, and was apparently not yet satisfied when the supply was exhausted.

A feeding experiment was tried on the common Texas horned toad (*Phrynosoma cornutum*), or horned frog, as it is sometimes called. The specimen in question was in a cornfield badly infested by the bollworm, and seemingly on the alert in search for food. A large bollworm was thrown upon the ground a foot or two away from him, and it had scarcely uncurled itself to crawl away before he perceived and quickly devoured it. The same action was repeated in rapid succession until seven had been eaten and the animal was gorged with food. The worms were just of the size which the toad might encounter in nature wandering about in search of a suitable place to pupate. From this it would seem quite likely that when the more conventional diet of the animal (consisting almost entirely of the large red "agricultural ant") is scarce, it may turn its attention to the bollworm.

It is very generally believed that birds exert an important influence in insect control. During their nesting period particularly, large numbers of insects are fed to the young, and in normal food habit many species of our commoner birds are largely insectivorous.

It is commonly stated that various birds frequenting cotton and corn fields destroy a greater or less number of bollworms along with other insects. The number of species which have been actually observed feeding on bollworms, however, or in which the insect has been found in stomachs, is very limited. During the present investigation but one wild bird was observed to actually catch a bollworm. This was a red-bellied woodpecker (*Centurus carolinus*), which Mr. Jones observed extracting a bollworm larva from an ear of field corn. The red-headed woodpecker (*Melanerpes erythrocephalus*) may often be seen working at the ends of roasting ears in a way to suggest that

bollworms are being sought. Probably in most instances it is simply feeding on the soft, milky kernels, and the destruction of bollworms is more or less accidental. According to Dr. C. Hart Merriam, of this Department, bollworms were found in the stomach of the great-tailed grackle (*Megaquiscalus major macrourus*). Mr. Glover[a] records an instance of the common kingbird or bee martin (*Tyrannus tyrannus*) catching a bollworm moth, and also mentions that bollworm moths formed part of the daily diet of some young mockingbirds, as evidenced by the dismembered wings on the ground beneath the nest. Mr. L. N. Bonham[b] records "blackbirds" as feeding on bollworms in Ohio during a period of drought. While the birds were not actually observed with the insects, the evidence presented is strong that the larvæ were being extracted from the ears of corn in the field in which the birds had settled.

Although direct evidence of the usefulness of birds in destroying bollworms is meager, yet it is practically certain that many common farm birds destroy these among other injurious farm and orchard insects. For practical as well as æsthetic reasons, therefore, they should be protected and encouraged as much as possible.

Reference may here be made to the considerable service rendered by barnyard fowls in destroying insects. Chickens and turkeys have at different times been observed feeding on bollworms. In one case an individual turkey of a large flock in an alfalfa field was observed to pick up twenty larvæ in one minute by the watch, and the distended crops of the turkeys of the entire flock gave evidence of the destruction of a large number of bollworms.

The following list of birds occurring in and about cotton fields in Texas was kindly furnished by Doctor Merriam. Those species likely to feed on bollworms, as indicated by Professor Beal, are marked with an asterisk.

*Bobwhite (*Colinus virginianus* and *Colinus v. texanus*).
Mourning dove (*Zenaidura macroura*).
*Mississippi kite (*Ictinia mississippiensis*).
*Sparrow hawk (*Falco sparverius*).
*Yellow-billed cuckoo (*Coccyzus americanus*).
Red-headed woodpecker (*Melanerpes erythrocephalus*).
Red-bellied woodpecker (*Centurus carolinus*).
Flicker (*Colaptes auratus luteus*).
Scissor-tailed flycatcher (*Muscivora forficata*).
Kingbird (*Tyrannus tyrannus*).
Crested flycatcher (*Myiarchus crinitus*).
*Blue jay (*Cyanocitta cristata*).
*Crow (*Corvus brachyrhynchos*).
*Cowbird (*Molothrus ater*).
*Red-winged blackbird (*Agelaius phœniceus*).

[a] Monthly Report, 1866, p. 285.

[b] Insect Life, II, p. 47.

*Meadowlark (*Sturnella magna*).
Orchard oriole (*Icterus spurius*).
Baltimore oriole (*Icterus galbula*).
*Crow blackbird (*Quiscalus quiscula æneus*).
*Great-tailed grackle (*Megaquiscalus major macrourus*).
Western lark sparrow (*Chondestes grammacus strigatus*).
Chipping sparrow (*Spizella socialis*).
Field sparrow (*Spizella pusilla*).
*Towhee (*Pipilo erythrophthalmus*).
*Cardinal (*Cardinalis cardinalis*).
Blue grosbeak (*Guiraca cærulea*).
Indigo bunting (*Cyanospiza cyanea*).
Painted bunting (*Cyanospiza ciris*).
Summer tanager (*Piranga rubra*).
Northern yellow-throat (*Geothylpis trichas brachidactyla*).
Yellow-breasted chat (*Icteria virens*).
*Mockingbird (*Mimus polyglottos*).
*Catbird (*Galeoscoptes carolinensis*).
*Brown thrasher (*Toxostoma rufum*).
Carolina wren (*Thryothorus ludovicianus*).
Texas wren (*Thryomanes bewickii cryptus*).
Tufted titmouse (*Bæolophus bicolor*).
Blue-gray gnatcatcher (*Polioptila cærulea*).
*Robin (*Merula migratoria*) (in early spring and late fall).
*Bluebird (*Sialia sialis*).

PARASITES.

Under this head we have to consider a very important factor in the natural control of the bollworm. There are two stages in the life history of the bollworm when the destructive work of parasites is most effective. These are the egg and the young larva, two stages which are passed before the bollworm has done the greater part of its damage. As the method of attack is so different in each case it will be well to consider them separately.

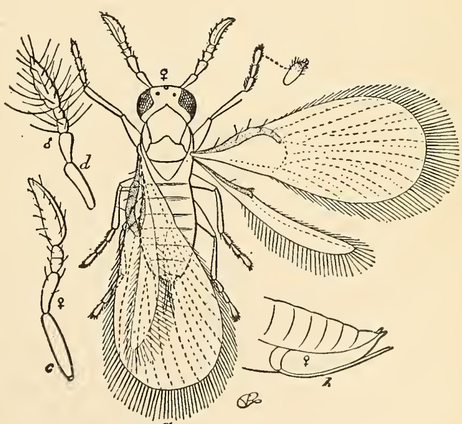

FIG. 20.—*Trichogramma pretiosa* (from Riley).

PARASITES OF THE EGG.

There are two small species of Hymenoptera which are parasitic on bollworm eggs, but one of them is of very rare occurrence and has but little economic significance. The second, *Trichogramma pretiosa* Riley, is extremely abundant and of great value (fig. 20). The eggs of the

parasite are deposited inside the bollworm eggs by the female, which is provided with a sharp ovipositor capable of piercing the hard chitinous shell of the egg. The young parasitic grubs eat out the contents of the egg, thus preventing hatching.

The following tables, compiled from a large number of records, show very graphically the large percentage of eggs which fail to hatch on account of these parasites:

TABLE XLV.—*Percentages of parasitized eggs on corn, 1903.*

Date of examination.	Number of eggs examined.	Locality.	Eggs on—	Per cent parasitized.
May 31	194	Victoria, Tex	Corn silks	84
June 1	100	do	Corn leaves	72
Do	144	do	Corn silks	83
June 3	283	do	Corn leaves	70
Do	747	do	do	44.8
August 8	100	Calvert, Tex	do	26

TABLE XLVI.—*Percentages of eggs parasitized, 1904.*

Date of examination.	Number of eggs examined.	Locality.	Plant.	Per cent parasitized.
May 16	150	Paris, Tex	Corn	59.3
June 3	10	do	do	70
June 10	20	do	do	80
August 1	40	do	do	50
August 12	31	do	Corn silks	58
Do	32	do	Corn leaves	68.7
Do	10	do	Tobacco leaves	30
August 14	40	do	Corn leaves	100
August 16	40	do	Cotton	22.5
August 20	40	do	Corn leaves	92.5
Do	40	do	Corn silks	62.5
August 29	40	do	Corn leaves	75
September 3	34	do	Cotton	35.5
September 7	44	do	Tomato leaves	86.5
September 24	40	do	Corn leaves	82.5
October 19	28	do	do	43

	Per cent.
Observed average parasitized during 1903	63.3
Observed average parasitized during 1904	63.4
General average, all observations	63.35

Glancing down the table, it will be noted that the maximum parasitization is on corn leaves, with corn silks next in susceptibility, and parts of the cotton plant considerably in the rear. This may possibly be due to the hindrance offered to the locomotion of the Trichogramma during the process of oviposition by plant hairs, since the leaves of corn are more nearly free from these than the other objects mentioned.

The first appearance of Trichogramma in the spring corresponds approximately with the first general occurrence of bollworm eggs on

corn, which in 1904 was about the middle of May in northern Texas. After this time there is always a continual supply of eggs, owing to the laying by belated moths of the spring generation; and throughout the season the smaller number of eggs between the more marked generations serve to furnish a continuous supply of food for the parasites.

Experiments were conducted in the laboratory by Mr. Girault to ascertain the length of the life cycle of Trichogramma and the number of broods during the season. The first generation, started on May 26, required eleven days, but the time for the succeeding generations gradually decreased to eight days during July and August, and lengthened to eleven again by the beginning of October. During the whole summer some fifteen consecutive generations were under observation. Some of the adults of the fifteenth generation apparently do not emerge from the pupa state, although a large proportion of them do. These may, under favorable conditions, produce other scattering broods, but it is probable that most of them must die before finding eggs which they can parasitize. Those remaining in the pupa stage no doubt hibernate in this condition, not emerging until the beginning of the following summer.

When a bollworm egg is discovered by the nervous little Trichogramma, as she darts about in search for one, she will quickly examine it by crawling over the surface and tapping it with her sensitive antennæ. If it seems suitable to her, she quickly sets about inserting her thin, flexible ovipositor at the desired spot. After about half a minute this has pierced the thick shell and is well within the egg, allowing the parasite to deposit her egg near the center of the bollworm egg. The ovipositor is then withdrawn and the parasite is ready to repeat the process. The laying of each egg requires about two minutes. On several occasions we have seen Trichogramma ovipositing in the field. The procedure seems to be essentially the same as that observed in the laboratory, but necessarily rather hard to observe without the aid of a rather powerful lens. Apparently the insect has no means of ascertaining whether a bollworm egg has already been parasitized, since eggs known to contain Trichogramma eggs are often selected by a second female for oviposition. This second parasitization, however, seems to occur only before the egg begins to turn black, which would suggest that the Trichogramma detects an egg already parasitized by its dark color.

It the laboratory it was found that the Trichogramma could be raised on infertile bollworm eggs, although the latter normally shrivel up shortly after they are laid. As infertile eggs are laid very rarely in nature, this discovery is of more scientific than practical value. Mr. Girault's observations tend to show also that Trichogramma may,

under certain conditions, reproduce parthenogenetically. Observations on breeding such minute insects are difficult to make, however, and must always be attended with some uncertainty. The sex of the parthenogenetically produced individuals was not determined. From a parasitized egg there emerge, on an average, about two parasites, although often as many as four, and sometimes only one, have been bred. The adults live at most only about four days, and their average life is but one and one-half days. During this stage it is probable that they feed but little, although they have been observed to feed on fruit juices in the laboratory and might easily find food in nature at the nectaries on the cotton squares or leaves.

Fig. 21.—Bollworm egg parasitized by *Trichogramma pretiosa* (original).

For some two days after the eggs are stung by the parasite they show no external sign of parasitism, but generally on the third day they rapidly become dusky and translucent, which color changes to an opaque bluish black soon after. This color persists very distinctly, even after the parasites have emerged, and always serves to distinguish a parasitized egg. Their exit is accomplished by cutting a rounded, often jagged, hole in the shell of the host egg (see fig. 21). Although several parasites may come from a single egg, generally but one exit hole is present, it being in most cases on one side. Copulation usually takes place within a few hours after emergence and oviposition follows almost immediately.

DESCRIPTION OF TRICHOGRAMMA PRETIOSA RILEY.

Trichogramma is an extremely minute Chalcis-fly, scarcely visible to the unaided eye, and resembling closely the numerous other species belonging to this group. It can be recognized readily, however, by the characteristic arrangement of the hairs on the front wings, i. e., in regular rows, and by the presence of only three tarsal joints.

Length 0.3 to 0.43 mm., the males being usually the smaller. Color pale yellow, as a rule, although some specimens are almost black. Eyes dark red and wings hyaline. Head wider than the thorax; antennæ eight-jointed, pedicel about two thirds the length of the scape, one small ring joint, the two joints of the funicle equal, together shorter than the pedicel, club conic ovate, a little longer than the scape; funicle and club beset with many long hairs in the male and with short ones in the female. Hairs of the front wings arranged in about fifteen lines. Abdomen not so wide as the thorax, but as long as the head and thorax together.

Eggs attacked by this little parasite have been obtained at various localities in South Carolina, Georgia, Florida, Alabama, Texas, and Arkansas, so that there can be no doubt of its very general distribution throughout the cotton-growing States. It is also a very useful parasite of the eggs of the cotton caterpillar.

Of the hundreds of specimens bred out during the past summer from eggs kept in the laboratory by Mr. Girault the proportion of the sexes seems to be about equal. Both sexes frequently emerge from the same bollworm egg.

The eggs of the bollworm are attacked by a second parasite belonging to a second group, the Proctotrypoidea, *Telenomus heliothidis* Ashm. (see fig. 22). This species was first discovered by Mally and described from a single specimen bred by him from an egg of the bollworm. Two females and a single male specimen issued on May 30, 1904, from bollworm eggs kept in the laboratory at Paris, Tex. These eggs had been collected on cornsilks in a field and were laid by moths of the first generation. No more specimens of this parasite were obtained during the year, although hundreds of eggs were under observation. It seems probable, therefore, that it is very rare, or possibly that it attacks the eggs of some other insect also.

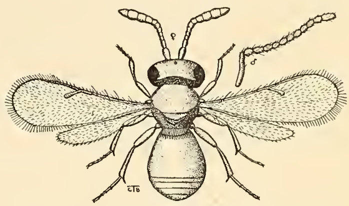

FIG. 22.—*Telenomus heliothidis*—much enlarged (original).

DESCRIPTION OF TELENOMUS HELIOTHIDIS ASHMEAD.

Female.—Length 0.6 mm. Black, smooth, impunctured, head large, much wider than the thorax; eyes pubescent. Antennæ dark brown, the flagellum twice as long as the scape, the pedicel stout and as long as the first and second funicular joints together, the third and fourth about equal, not longer than thick, the fifth larger, moniliform, club four-jointed, the second and third joints quadrate, the last conic. Thorax ovoid, faintly pubescent, almost bare, mesonotum without furrows, metathorax short, rounded, unarmed. Wings hyaline, with a long fringe; submarginal vein joining the marginal at about one-fourth the length of the wing. Abdomen not longer than the thorax, broadly truncate behind, the first segment exceedingly short, striate, second segment not, or very little, longer than wide. Legs dark brown, the coxæ black, and the tarsi whitish.

Male.—Differs from the female as follows: Length 0.65 mm., mandibles brownish yellow, antennæ longer, filiform, about as long as the body; flagellum three times as long as the scape, pedicel and first flagellar joint about equal and rounded moniliform, following joints a little smaller, last one-half longer and obtusely conic. Bases of the tibiæ yellowish.

PARASITES OF THE LARVA.

Owing to the cannibalistic habits of the bollworm, the breeding of parasites is a rather tedious process, since each larva must be confined in a separate breeding jar. This is most easily accomplished by con fining the desired number of larvæ under a series of inverted tumblers, each provided with a small boll or bit of other suitable food. In prac tice we have found that pieces of green cowpea pods are most avail-

able, as they are easily handled and the larvæ thrive on them. With such an arrangement the food can readily be changed and the bollworm examined whenever desired. By using this method large numbers of parasites were bred out at the laboratory.

The habits of the bollworms in feeding on corn are such that they are well protected from parasites after the first few days of their life, during which time they have been boring down through the silk into the ear. When once well inside the ear it is practically impossible for parasites to reach the larva, unless it should leave the ear, which is very rarely the case. These conditions explain the small percentage of parasites shown in the following table:

Table XLVII.—*Percentages of larvæ parasitized on corn, 1904.*

Date collected.	Locality.	Size of larvæ.	Number collected.	Number parasitized.	Per cent parasitized.
May 15	Hempstead, Tex	Miscellaneous	18	0	0
May 30	Dallas, Tex	Full-grown	45	0	0
June 1	Ladonia, Tex	Miscellaneous	19	0	0
June 14	Paris, Tex	Large	75	0	0
June 26	Corsicana, Tex	Miscellaneous	35	0	0
July 14	Paris, Tex	do	25	0	0
Aug. 18	do	Large	105	0	0
Sept. 10	Batesburg, S. C	do	34	0	0
Sept. 10	Pine Bluff, Ark	Miscellaneous	22	1	4.5
Sept. 12	Montgomery, Ala	Large	34	1	3.0
Sept. 30	Paris, Tex	Miscellaneous	30	1	3.0
	Average				1

Feeding on cotton, larvæ are much more exposed to the attack of parasites, as they must move about in search of fresh squares or bolls; and even when partially hidden within a square or boll a larva is not completely immune. The following table shows very clearly the greater proportion of parasites on cotton as compared with corn:

Table XLVIII.—*Percentages of larvæ parasitized on cotton, 1904.*

Date collected.	Locality.	Size of larvæ.	Number collected.	Number parasitized.	Per cent parasitized.
Aug. 20	Paris, Tex	Large	184	31	16.75
Aug. 25	do	Young	40	27	67.50
Aug. 31	do	Miscellaneous	104	53	51.00
Sept. 16	Tupelo, Miss	Small	13	9	69.00
	Average				51.00

From these data it is evident that practically one-half of the larvæ of the August brood are destroyed by parasites. This is especially important when we recall that it is this brood which causes the greatest damage to cotton. The insect responsible for this wholesale elimination is a small hymenopteron belonging to the family Braconidæ. It is more fully treated in the following pages.

It will be noticed by referring to the table that the greater percentage of parasites come from the smaller larvæ; or, in other words, that the larvæ are destroyed before they are half grown and consequently before they have done the greater part of their injury to the plants.

HYMENOPTEROUS PARASITES.

Practically all the parasites bred from the young larvæ belong to the same species, *Microplitis nigripennis* Ashm., of the family Braconidæ. This species was first bred in the laboratory from a larva collected on tobacco at Paris July 5, 1904, but it was not observed in any numbers until the middle of August, when a large percentage of the bollworms feeding on alfalfa were found to be parasitized by it. Its frequent occurrence on cotton after that time has been referred to.

The eggs of the parasite are deposited in larvæ which are about 10 or 12 mm. in length, or much more rarely in larger specimens. After it has been stung by the Braconid, the larva continues to feed, but at a much diminished rate, for two or three days. It now becomes very sluggish and eats the involucre of the square or boll in a rather desultory manner, chewing it into small bits, many of which it fails to swallow. These small pieces usually remain webbed together loosely by delicate strands of silk spun by the bollworm, and present quite a characteristic appearance. By the time the parasitic grub is full-grown, the larva has ceased feeding entirely and is scarcely larger than when first attacked. The Microplitis now bores its way out through the skin of the quiescent bollworm, leaving a large black scar (see Pl. XIX, fig. 1) to mark the point of its emergence, which is generally on one side of the body, near the first pair of prolegs. In one case the grub was watched during the act of emerging from the bollworm. It had protruded the pointed head and was gradually working its fleshy body through the small hole in the larva's skin. In doing this the body had to be constricted dumb-bell shape in order to pass through the small orifice. Once free from the larva, it spins its pupal cocoon (see Pl. XIX, fig. 1, and text fig. 23) on some surrounding object, generally a stem or a leaf, spending several hours in this work. The cocoon is about 5 or 6 mm. in length, oval in shape, pale dingy yellow in color, and furnished with a few coarse longitudinal ribs. When first spun it is almost white and rather delicate. After a few hours, however, it acquires its mature color and its consistency becomes very tough.

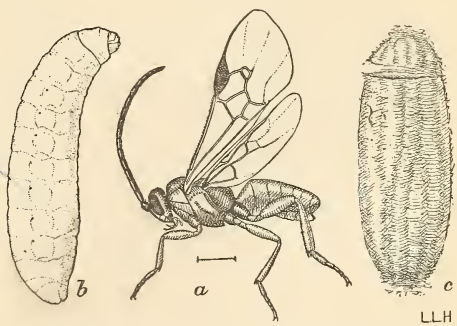

FIG. 23.—*Microplitis nigripennis:* adult, larva, and cocoon (original).

After the parasite has left it the bollworm usually lives for several days, but does not feed at all during that time. Before death it gradually shrinks and dries up. Larvæ which are parasitized almost always acquire a pale yellowish color and shriveled appearance, which is quite characteristic, even before any other external sign of the parasite is evident.

Some of the specimens bred out in the laboratory were confined over night with several bollworms in a breeding jar, and from one of these an adult parasite was reared. The life cycle is about three weeks, some nine days of which are spent in the pupal stage.

At no time have we obtained more than a single specimen of Microplitis from one bollworm.

DESCRIPTION OF MICROPLITIS NIGRIPENNIS ASHMEAD.

Length, 4 to 5 mm. Black, except the abdomen and legs, which are usually reddish yellow. Wings very strongly infuscated. Antennæ 17-jointed. Head and thorax shining black, metathorax coarsely reticulated, with a median carina. Abdominal petiole black at base and remainder of abdomen sometimes much darkened. Legs reddish, the coxæ more or less black at base. Wings very dark, veins blackish, second cubital cell about as high as long, subtriangular.

FIG. 24.—*Perilampus hyalinus:* adult and cocoon (original).

We have bred over fifty specimens of this species, mostly from larvæ collected in northern Texas, although the following localities are also represented: Montgomery, Ala.; Tupelo, Miss., and Pine Bluff, Ark. It was bred from larvæ collected on the following plants: Cotton, corn, alfalfa, and tobacco.

The Microplitis is attacked by two species of secondary parasites, but fortunately neither of them has been bred in large numbers.

The first, *Perilampus hyalinus* Say, a brilliant metallic blue chalcidid fly (see fig. 24), was bred out on two occasions. The first specimen came from Pine Bluff, Ark., September 13, 1904, and the second from Ladonia, Tex., October 14, 1904. The Perilampus issues by gnawing an irregular hole through the end of the Microplitis cocoon.

The second, *Mesochorus americanus* Cress, is a well-known secondary parasite, infesting various species of Braconidæ. It was bred on only one occasion, during August, 1904.

The little chalcidid fly *Euplectrus comstocki* Howard, which usually preys upon the cotton caterpillar, also attacks the bollworm, according to Prof. H. A. Morgan, who has bred the species,[a] but we have never met with it in Texas.

[a] Bul. La. Exp. Sta. No. 48, p. 159.

DIPTEROUS PARASITES—TACHINIDÆ.

There are a number of species belonging to this family of flies which are parasitic on the bollworm. The female fly deposits her eggs on the surface of the body of the larva, generally toward the anterior end. Sometimes but a single egg is laid, although a parasitized larva frequently bears several eggs attached to it. The eggs are of a pearly white color when first laid, but often turn darker when the embryo begins to develop in them. They are somewhat less than a millimeter in length, elongate in shape, with rounded ends and parallel sides. As soon as the egg hatches, the parasitic grub bores into the bollworm through the skin and begins feeding upon its fatty tissue, undergoing a very rapid growth. Even when a number of eggs are attached to a single larva, it is rare for more than one parasitic grub to mature in the bollworm.

The species of the family resemble each other so closely that it is almost impossible for anyone not familiar with them to recognize the different forms. The table below gives a summary of the species bred.

TABLE XLIX.—*Species of Tachinidæ bred from bollworms during 1903 and 1904.*

Name.	Locality.	Date.	Food plant of bollworm.
Winthemia 4-pustulata Fab	Paris, Tex	Aug. 22, 1904	Alfalfa.
Exorista ceratomiæ Coq	Calvert, Tex	Sept. 4, 1903	Cotton.
Euphorocera claripennis Macq	Paris, Tex	Aug. 18, 1904	Alfalfa.
Gonia capitata De G	Ladonia, Tex	Nov. 2, 1904	Do.
Do	Paris, Tex	Nov. 7, 1904	Do.
Archytas piliventris v. d. W	Victoria, Tex	May 26, 1903	Corn.
Do	do	May 29, 1903	Do.

Of these it is probable that the first is most valuable in northern Texas, and the last mentioned (see fig. 25) in the southern part of the State.

In addition to this list the following species are known to be parasitic on the bollworm, although they were not bred by us during the past two seasons: *Frontina armigera* Coq., *F. frenchii* Will., and *F. aletiæ* Riley. The first was bred by Coquillett[a] from bollworms collected at Los Angeles, Cal.; the second by Riley[b], and the last by Trelease[c].

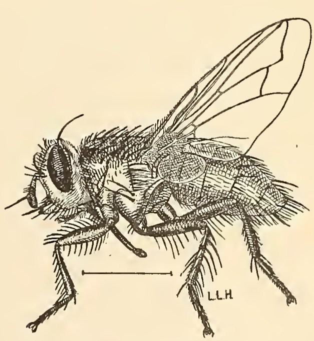

FIG. 25.—*Archytas piliventris:* adult fly (original).

Early in November a lot of eighty-seven larvæ, mostly full-grown, were collected by Mr. Girault in an alfalfa field at Paris, and forty of them, or nearly 50 per cent, bore tachinid fly eggs on their bodies. One had as many as eleven, but most of

[a] Insect Life, I, p. 331.

[b] Fourth Missouri Rept. p. 129, footnote.

[c] Fourth Rept. U. S. Ent. Com., p. 377.

them only two or three. It proved impossible to rear the parasites from most of these larvæ, for the latter were nearly all affected with a bacterial disease and died before the parasites could attain full growth.

The records are very meager, but serve to show that Tachinidæ are of but little assistance in controlling the bollworm.

During the past season the life history of one parasite, *Winthemia 4-pustulata* Fab. (see fig. 26), was worked out. A female kept in the laboratory deposited eggs on three different bollworms, laying five on one, seventeen on another, and one on a third. The eggs are 0.8 mm. in length, elongate-oval in shape, and pearly white at first, but after twenty-four hours they turn to an orange-yellow color. The duration of the life cycle is as follows: Egg, two days; larva, three days; pupa, nine to ten days.

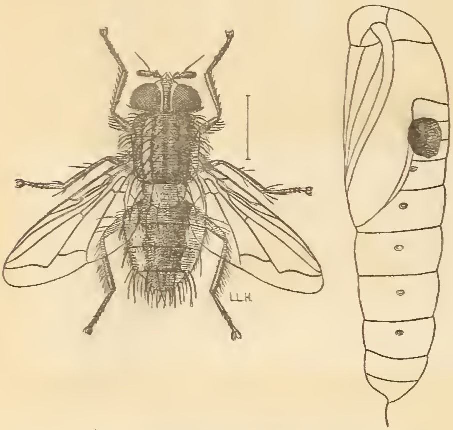

FIG. 26.—*Winthemia 4-pustulata:* adult and parasitized moth pupa (original).

Summarizing the conclusions to be reached from a study of the insect parasites of the bollworm, it is evident that the destructiveness of the third and fourth generations is materially lessened by them. During September, 1904, when the fourth generation should have been damaging much of the late cotton in northern Texas, it was almost impossible to find any bollworms on cotton, and the few to be obtained in the neighboring alfalfa fields were invariably attacked by parasites. At the same time adult specimens of Microplitis could almost always be collected in these locations by the use of the sweep net. Meanwhile, the late corn nearby, where the parasites could not get at the larvæ, was badly damaged.

Such evidence plainly suggests that the dearth of larvæ on cotton at this time must have been, in a measure at least, due to the good work of parasites.

DISEASES.

BACTERIAL DISEASE.

There is only one disease that plays an important part in the economy of the bollworm. It is one evidently caused by bacteria, although its exact nature has not been clearly worked out. Its effects are most clearly apparent among larvæ feeding on corn, more especially those of rather large size.

The appearance of a larva after the disease is well advanced is characteristic. The body loses its firm consistency and becomes quite flabby, while its color fades to a rather uniform greenish yellow. (See Pl. XIX, fig. 3.) The larva loses the power of coordinated movement, only wriggling or twitching spasmodically when disturbed, and soon begins to turn darker. Within a few hours after its death it assumes a purplish black color, and the whole internal contents liquefy more or less completely. When the skin is broken this liquid mass is seen to have a distinct reddish tinge.

Larvæ living in a humid atmosphere seem to be more susceptible to the disease. The following table, containing some of the more complete records made during the course of the work, will give a general idea as to the percentage of larvæ destroyed by this disease:

TABLE L.—*Percentage of larvæ destroyed by bacterial disease.*

Date of collection.	Locality.	Food plant.	Number collected.	Per cent diseased.
July 1, 1903	Victoria, Tex	Corn		2–3
Aug. 3, 1903	Calvert, Tex	do	300	4½
Aug. 4, 1903	do	do		6
Aug. 17, 1903	do	Alfalfa	81	10
May 28, 1904	Dallas, Tex	Corn	56	10
Aug. 20, 1904	Paris, Tex	Cotton	184	49
Aug. 25, 1904	do	do	40	5
Aug. 30, 1904	do	Corn	12	17
Sept. 24, 1904	do	do	111	63
Oct. 7, 1904	do	Alfalfa	17	12
Oct. 24, 1904	do	do	37	29

Averages: Corn, 18 per cent; cotton, 27 per cent; alfalfa, 17 per cent.

The great discrepancies in the different lots are in large part due to the fact that some counts were made by examining larvæ freshly collected, and others from larvæ kept in the laboratory for a considerable time, a few dying each day. The large percentages indicated in some of the columns, however, show plainly that under certain conditions a great proportion may succumb to this malady. One unfortunate circumstance is the fact that it is nearly always the larger larvæ which are attacked.

In the laboratory several cultures were made from a dried larva that had died from bacterial disease. After five days all the cultures had acquired a pinkish tinge, and each, when examined under the microscope, yielded a ciliated organism of a bright crimson color, readily visible with a one-twelfth-inch oil-immersion lens, without staining. Four healthy worms were infected from the cultures by pressing the head and mouth parts against the red gelatine. Of the larvæ thus infected, two died within two days with the symptoms of the bacterial disease; one escaped, and the fourth, full-grown when infected, pupated successfully. From one of the first cultures, two more were then started and after six days were characteristically red. These

experiments were conducted in a crude way, without the use of special bacteriological apparatus, and are, of course, open to question. They tend to show, however, the bacterial nature of the disease, the presence of a specific organism, and the possibility of contagion.

Another observation serves to show the contagious nature of the disease. It was noticed on August 15, 1904, that four larvæ had died in succession in as many nights in the same breeding jar, the dying bollworms having been daily replaced by new ones. At this time a thorough washing with hot water and soapsuds prevented future mortality in the jar. We have noted many other similar instances during the breeding work.

Quite often the larva has already entered the soil before it is apparently attacked, and, again, not infrequently a larva may die while in the act of constructing its burrow.

It is very noticeable that larvæ which have been injured or bitten by their fellows are much more susceptible than healthy specimens; in fact, a larva which has been but very slightly hurt scarcely ever escapes infection.

At present there seems to be no hope of making any practical use of the disease in controlling the bollworm, as has been done with some other species of injurious insects. It is an important factor, however, and helps to keep the pest in check.

SCAVENGERS FOLLOWING THE BOLLWORM.

In addition to the true parasites of the bollworm there are a number of insects acting as scavengers, some of which are often mistaken for parasites.

On numerous occasions we have observed minute flies, belonging to the family Phoridæ, hovering about the breeding jars which contained specimens of larvæ, pupæ, and adults; in fact, it is almost impossible to keep large numbers of bollworms or pupæ together without attracting these little scavengers. In one case the Phoridæ were allowed to oviposit upon a dead and decaying moth, and after a period of seventeen days the adults of a second generation appeared. They proved to be *Aphiochæta fungicola* Coq. In other lots of larvæ from various localities many specimens of *Phora incisuralis* Loew were obtained at different times during the summer, and doubtless other species might have been found if special search had been made for them. *Aphiochæta nigriceps* Loew (*Phora aletiæ* Comst.) has been observed[a] to feed upon the dead pupæ and adults in the same way, and was at first thought by Comstock[b] to be a true parasite. This has been abundantly disproved, however, and none of the species have any especial economic significance, since they never attack living bollworms in any stage.

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[a] Riley, Fourth Rept. U. S. Ent. Com., p. 117. [b] Rept. Cotton Ins., p. 208.

The presence about the breeding jars of flies belonging to species of Sarcophagidæ was frequently noticed throughout the summer, but only once were any adults bred from jars containing bollworms. In this case some living pupæ had been buried in finely sifted earth in a glass jar covered with cheese cloth to determine the ability of the emerging moths to pass through a stratum of loose soil. One morning after several moths had appeared, three small specimens of *Helicobia helicis* Town. appeared also. On exhuming the remaining pupæ the fly puparia were unearthed close to an empty bollworm pupa case. Whether the eggs of the fly were in the soil, whether they were laid through the cloth, or whether the eggs or young larvæ were already on one of the live pupæ, would be impossible to say. Hubbard[a] records an almost exactly similar instance. Whether this is a case of true parasitism remains very doubtful.

Larvæ of another fly, *Euxesta annonæ* Fab., were obtained by Mr. Jones at Wharton, Tex., on July 20, 1904, feeding on the juices of a dead bollworm, and from them adults were bred out in the laboratory. The flies are often to be seen about corn plants during the earlier part of the season, and no doubt their larvæ also feed on decaying vegetable matter, like the other species of the genus.

The other small muscid flies, *Drosophila punctulata* Loew and *D. ampelophila* Loew, were bred from cotton bolls decaying as the result of bollworm injury.

Monocrepidius vespertinus Fab. and another larger click beetle also act as scavengers after the bollworm.

A small nitidulid beetle (*Conotelus obscurus* Er.) is very common in ears of corn which have been previously injured by the bollworm. In a badly damaged ear often as many as thirty or forty of these little black beetles may be present when the corn is nearly ripened. They do not attack the corn unless it has been already injured by the bollworm. Several other species of Nitidulidæ also frequent the damaged ears and bolls.

METHODS OF BOLLWORM CONTROL.

CULTURAL METHODS.

By reason of its feeding habits, the control of the cotton bollworm, as compared with many insects, presents unusual difficulties. On cotton, corn, and tomatoes, particularly, it feeds on the interior plant tissues, and is therefore not amenable to such insecticidal treatment as is effective for many related species. Further, it is much less subject to the attack of parasitic and predaceous enemies than insects feeding

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[a] Fourth Rept., p. 110.

in more exposed situations, and the bollworm is thus able to develop with comparative freedom from these important natural checks.

In the case of many insects affecting staple crops their best control is often to be found in the adoption of some change in farm practice that will take advantage of some peculiarity in the life and habits of the pest. Such changes are usually quite in line with better farming, and involve no extra outlay of labor and money not warranted for other reasons than those of insect control. The bollworm falls easily into this class of insects, and the means which are of most importance in avoiding injury consist in certain changes in agricultural practice which are in themselves desirable, aside from their influence on the pest.

Attention has elsewhere been called to the relation of the farming methods in vogue to bollworm injury to cotton. Experiments during the past two years indicate that by improved cultural methods much may be done to insure a crop of cotton, even during years of severe bollworm injury. Detailed results of field experiments have been given in Farmers' Bulletins Nos. 191 and 212, to which the reader is referred. The value of the so-called cultural method lies in the fact that cotton is not attacked in force until the field corn of the surrounding country, the favorite food of the bollworm, has begun to yellow and ripen and is no longer attractive to the moths for egg-laying purposes. The moths, therefore, concentrate in the cotton fields, obtaining their food from the nectaries on the squares and flowers of the cotton plant, and on these latter they deposit the bulk of their eggs. This time of migration to cotton will vary somewhat, depending on the relative earliness of surrounding corn, but will average, one year with another, about the 1st of August, for the central and northern parts of the cotton belt.

Another fact to be mentioned in this connection is the comparative immunity of the larger and maturer cotton bolls to attack by bollworms, as compared with the smaller bolls and squares. This is indicated on page 72. These two circumstances in the natural history of the insect permit, by the use of improved cultural methods, of the production of a fair crop of cotton ahead of danger from bollworm injury in August.

The importance of the early production of a maximum number of advanced bolls is therefore evident, and the cultural method involves the employment of all such means as will contribute to that end, such as—

(1) Thorough plowing of land in the fall to destroy as many hibernating pupæ as possible.

(2) The use of seed of early-fruiting varieties.

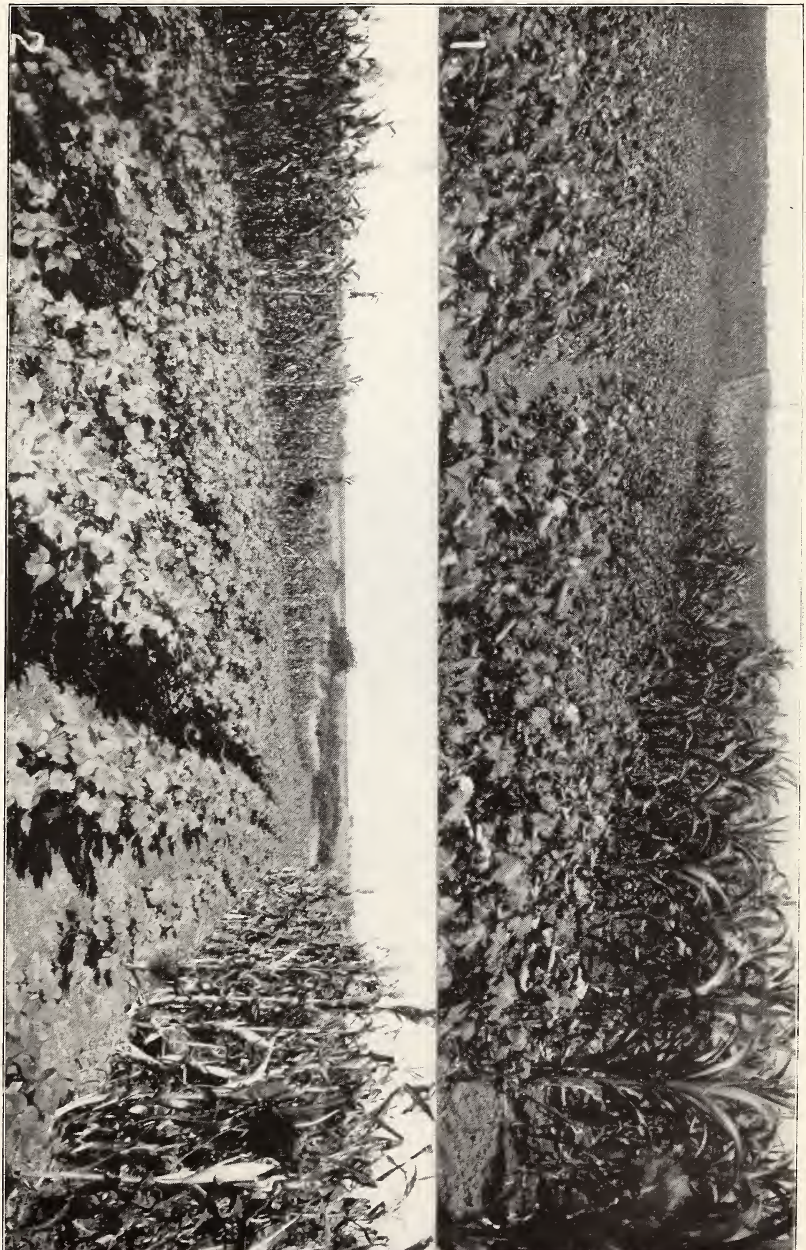
(3) The use of fertilizers to hasten and increase fruit production.

(4) Early planting in the spring.

(5) Early and thorough cultivation.

RELATIVE EARLINESS OF KING AND MYERS VARIETIES OF COTTON.

Plants from field treated in all respects alike (original).



PROPER AND IMPROPER USE OF CORN AS A TRAP CROP.

Fig. 1, Proper use of corn as a trap crop; corn will be in silk about August 1; fig. 2, improper use of corn as a trap crop; corn was planted at usual time in the spring and was yellow and hard by August 1 (original).

FIG. 1.—POISONING COTTON BY POLE AND BAG METHOD (ORIGINAL).

FIG. 2.—POISONING COTTON BY USE OF SPRAY PUMP (ORIGINAL).

FIG. 1.—POISON "BLOWER" FORMERLY MUCH USED IN DESTROYING COTTON CATERPILLARS, USEFUL AGAINST BOLLWORMS (ORIGINAL).

FIG. 2.—MACHINE USED IN COLLECTING BOLLWORMS FROM COTTON PLANTS (ORIGINAL).

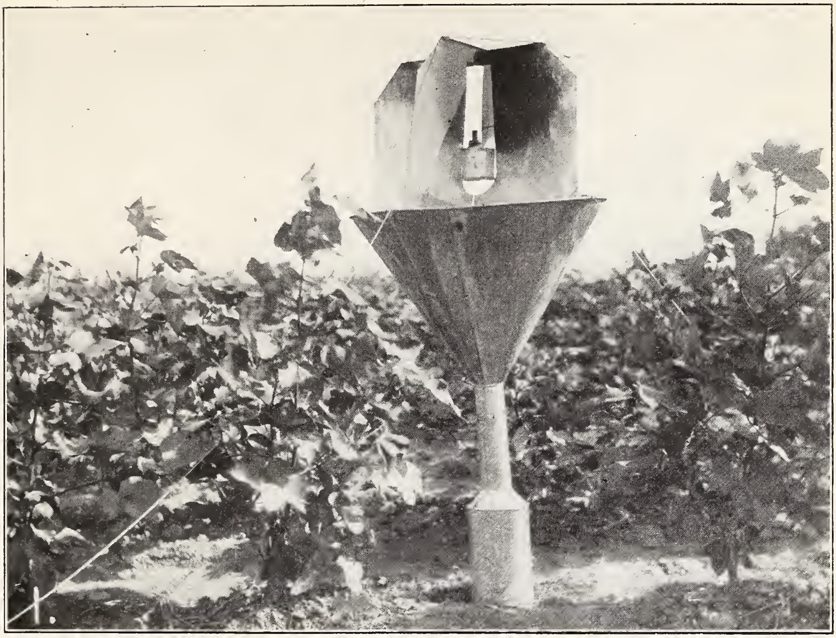


FIG. 1.—LIGHT TRAP USED IN EXPERIMENTS TO ATTRACT MOTHS TO LIGHT (ORIGINAL).

FIG. 2.—PANS OF BAIT USED IN EXPERIMENTS TO ATTRACT MOTHS TO POISONED SWEETS (ORIGINAL).

The cultural method begins with thorough preparation of land in the fall, winter, or early spring for the succeeding crop, by which means hibernating pupæ in the soil are in many cases destroyed. As a female moth appearing in the spring from a hibernated pupa may be the progenitor of many thousands of bollworms by early August, the importance of their destruction by thorough fall and winter plowing is evident.

Experiments made with fertilizers during 1904 on several types of soil, including the so-called sandy soils of east Texas, the post oak, gray prairie, river bottom, and black waxy soils of central and north Texas indicate that these are very useful in the production of an early and large crop of cotton (see Pl. XX for views on one of the Department's experimental farms in 1904). The accompanying diagram (fig. 27), compares the yield, with respect to earliness and quantity of

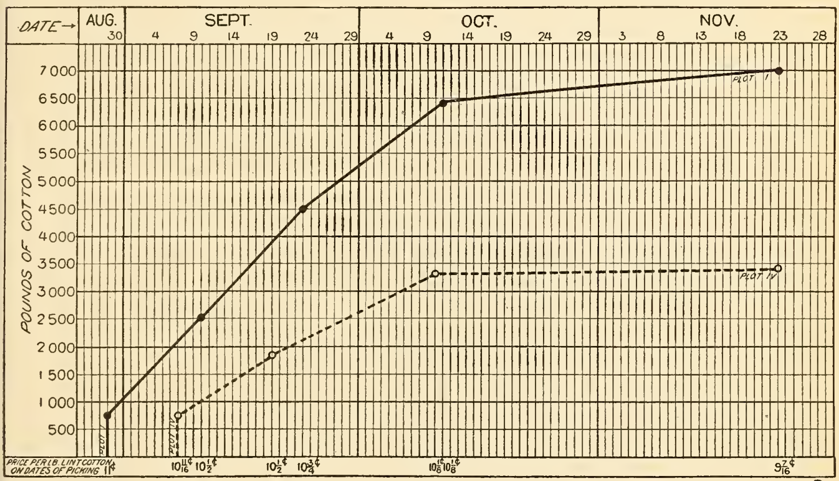


FIG. 27—Diagram showing comparative earliness and quantity of cotton crop from fertilized and unfertilized plats (from Quaintance and Bishopp).

seed cotton, from two plats of the experiment farm at Pittsburg, Tex. Plat 1 was treated with a fertilizer analyzing phosphoric acid 10 per cent, potash 2 per cent, at the rate of 300 pounds per acre. Plat 4 was unfertilized, the treatment in all other respects being the same.

Specific recommendations as to the quantity per acre and kind of fertilizers to be used may not be given as the result of one year's experimentation. Simply the fact of their utility is pointed out. Planters should arrange for a series of tests calculated to answer these respective questions for their own soils.

Of equal importance is the use of seed of varieties with an inherent tendency to begin fruiting early in the growth of the plant, thus insuring an early crop (see Pl. XXI, illustrating comparative maturity of King and Myers cotton treated the same throughout the

season). This habit of early fruiting is more characteristic of the shorter-jointed sorts than of the longer-jointed varieties.

These desirable qualities, viz. early fruiting, prolificacy, good staple, etc., may be perpetuated and improved by seed selection, and special attention should be given to this work. The importance of the use of selected early-fruiting varieties, as compared with native "run-down" gin seed, has been illustrated many times in the course of these investigations. In 1903, on the plantation of Capt. B. D. Wilson, at Hetty, Tex., under conditions of severe bollworm injury, early-planted early-fruiting cotton produced an average of 1,348 pounds of seed cotton per acre, as against 187 pounds of early-planted but later-fruiting gin seed.

The importance of planting as early in the spring as practicable has been recognized by planters for many years, and this has been about the only practice employed looking to the avoidance of bollworm injury. Best results from this work have often not been secured, however, because of the use of gin seed of unknown parentage and variety. No fixed dates may be given for the planting of cotton, but the effort should be to plant as early as possible, even though danger from frosts may not have entirely passed. The advantage gained in early planting more than compensates for the injury by frost during occasional years.

Early and thorough cultivation is an important factor in the cultural method of producing early cotton. Early chopping out of the plants will permit of free branching and consequent square production. The fertility of the soil, either native or introduced in the way of fertilizers, may be used by plants only in a liquid condition. Hence, for the conservation of moisture and other reasons, timely and frequent cultivation are of the utmost importance.

The steps in the production of early cotton, outlined above, include the principal recommendations for the growing of cotton in the presence of the boll weevil. It is therefore seen that injury from the cotton bollworm and the cotton boll weevil may be best avoided by the adoption of one and the same course of improved farm practice. The spread of the latter species will render imperative the adoption of these methods in profitable cotton culture, and along with this change the ravages of the bollworm during normal seasons should become less and less.

TRAP CROPS.

The preference of the bollworm for corn, as compared with its other food plants, permits of the use of this plant in a way to protect cotton from injury. In general, protection will be needed only from the August generation of larvæ, and this may be secured by planting corn in belts through the cotton fields at a time that will result in its being in

tassel and silk by the 1st of August (see Pl. XXII, fig. 1). Corn in this condition will receive the great majority of the eggs deposited by the moths which otherwise would be placed on the cotton plants. In planting cotton in the spring leave vacant strips across the field every 200 or 300 feet sufficiently wide for planting 10 or 12 rows of corn. Under favorable conditions of rainfall and with good cultivation, Mexican June corn planted by June 1 will be in prime silking condition by August 1. The corn should be allowed to mature and may be harvested in the usual way. Corn should not be planted in belts through the cotton field at the usual time in the spring. With the ripening of the corn the insects simply turn their attention to the adjacent cotton (see Pl. XXII, fig. 2). The planting of cowpeas in the trap corn belts is strongly recommended. Peas planted soon after the corn crop is up will ordinarily be in full blossom by early August and will serve to furnish the moths with an abundance of nectar for food, thus obviating the necessity of their visiting the adjacent cotton plants and the consequent deposition there of a certain proportion of their eggs. Much the same protection may be secured by the planting of late corn here and there over the plantation after such early maturing crops, as wheat, oats, etc. In all cases peas should be planted in the corn. The greatest benefit will result from the use of corn as a trap crop, when it is generally adopted by the planters of a neighborhood. On large plantations it is perfectly practicable to grow late corn in such a manner as to attract the bollworms from the plantation generally.

ARSENICAL POISONS.

It is the general belief among cotton planters that the bollworm may not be successfully poisoned on cotton, from the fact of its boring to the interior of bolls and squares and there feeding out of reach of insecticidal substances. Such belief is true only of the later stages of the larva. A newly hatched bollworm is so small a creature that it does not usually attract the attention of the average observer (see Pl. III, fig. 2), and the habits of the insect during this early larval existence are not generally taken into account. This unobserved period in the growth of the larva is about the only time during which poisons may be expected to exert any considerable influence in its control.

As has been elsewhere pointed out, the deposition of the eggs over the cotton plant and the habits of the newly hatched insect have an important bearing on the possibility of poisoning. Larvæ hatching from eggs placed on other parts of the plant than the tender growing tips, squares, and flowers, which are ordinarily soon penetrated, must spend some time in crawling around in search of tender food. During this aimless wandering of from several hours to a day or more,

frequent attempts are made at eating, and the larvæ would be readily poisoned if poisons were present on the plants. From a series of observations, both in 1903 and 1904, it was found that from 62 to 73 per cent of the eggs deposited by the bollworm moth on cotton were placed on the leaves, stems, leaf stalks, etc., or on other parts than the tender tips, squares, and flowers, so that the resulting larvæ could be destroyed by timely applications of poison. Ordinarily, poisons will be profitable only against the August generation of larvæ, and results will be much more pronounced during seasons of severe, as compared with moderate, bollworm injury. The plants should be kept poisoned from about the last week in July until about the second week in August, and later if the moths are seen to be abundant. During this period the eggs of the destructive August brood will be deposited, and the presence of poisons on the plants as the young larvæ are hatching will result in their destruction in large numbers.

As between the dusting and spraying methods of applying poison, the former seems more practicable (see Pl. XXIII, fig. 1). In dusting with Paris green, this should be used at about the rate of 2 to 3 pounds per acre for each application, the quantity varying somewhat with the size of the plants. In many cases, as with careless labor, it will be more economical to dilute the poison with cheap flour or dry slaked lime. Applications may satisfactorily be made by the usual pole and bag method. The use of geared poison blowers (see Pl. XXIV, fig. 1) would permit of the work being done more rapidly, which is very important. Applications of dry poison should be made at night, early in the morning, or late in the evening, when the plants are sufficiently wet with dew to insure its sticking. Paris green, applied in water, should be used at about the rate of 1 pound to 50 gallons, which amount will cover about 1 acre (see Pl. XXIII, fig. 2, illustrating Department's spraying experiments in bollworm control). The effect of a rain will be to wash the poison largely from the plants, and the application must necessarily be at once repeated. Applications of poisons, as above indicated, at intervals of a week or ten days, should keep the plants sufficiently poisoned to accomplish the desired results.

INEFFECTIVE METHODS OF COMBATING THE BOLLWORM.

During periods of serious bollworm injury planters often resort to various methods in their efforts to prevent the destruction of the crop. The burning of lights in the fields, the use of poisoned sweets, and the burning of sulphur were more or less practiced in 1903. These and similar methods have been shown, by numerous tests (see Pl. XXV, figs. 1 and 2) during the present investigation, to be of no practical value whatever, and attention is called to their futility that needless expense may be avoided in the future.

MECHANICAL DESTRUCTION.

Various types of machines for collecting cotton boll weevils from plants have been devised during the past few years. Some of these have been tried for collecting the cotton bollworm (see Pl. XXIV, fig. 2). In one case it was determined by a series of counts that about 10 per cent of the bollworms were collected by the machine in passing over the plants. It is considered possible that machines of this character may be so perfected as to render their use profitable in collecting bollworms.

METHODS OF BOLLWORM CONTROL ON CORN, TOMATOES, AND TOBACCO.

It must be acknowledged that thus far no satisfactory method of controlling the bollworm on sweet and field corn has been discovered. In those States where the insects hibernate in corn fields fall or winter plowing would be especially valuable in destroying the pupæ in the soil. Indeed, this practice is about all that may be recommended. During the present investigation tests have been made of several plans which have been recommended as of possible value. The plan to crush larvæ in the roasting ears, by hand or otherwise, does not, apparently, take account of the often numerous smaller larvæ to be found in the ear and which largely escape the effects of pressure fatal to the larger individuals.

Tests by Messrs. Bishopp and Jones of various substances placed on corn silks and ears, as black pepper, tar, sulphur, tobacco, crude petroleum, pennyroyal, creolin, pyrethrum, etc., as repellents to the moth in egg laying on these parts, gave negative results. While some substances apparently prevented the moths from ovipositing, their effect was to kill the portions treated.

The first brood of larvæ infesting "buds" of corn in the spring could in many instances be profitably sought for and destroyed by children, or plow hands in the course of their work, thus greatly lessening the numbers of the insects in succeeding generations. This practice uniformly followed by the farmers of a neighborhood should serve in the course of a year to so reduce the numbers of the bollworm that its injuries would be of little importance. Such a plan would be perfectly practicable in lessening injury to cotton, and its value would be in proportion to the extent of its adoption by the planters of a neighborhood.

No experiments in the control of the bollworm on tomatoes were undertaken during the present investigation. While there are but few data as to the deposition of eggs by the bollworm on tomato plants, it is certain that these are placed quite as promiscuously over the leaves, stems, etc., as was found to be true in the case of cotton

and corn. It would therefore appear that arsenical poisons might profitably be used in bollworm control on tomatoes, either alone or in fungicidal preparations designed to prevent fungous diseases. Applications of poisons should be made as soon as bollworm moths are observed in numbers in tomato fields. Two or three applications at intervals of a week or ten days should suffice to protect from important injury.

Early sweet corn may be planted in belts through the tomato field in a way that will afford much protection to the earliest fruit. A systematic effort toward the destruction of all larvæ found in these trap belts would contribute much toward lessening future injury.

Bollworm injury to tobacco is confined principally to the "bud." A treatment which has been in practice for many years by the tobacco growers of Florida, and possibly elsewhere, is to sprinkle into the "bud" at frequent intervals, by means of a tin can with perforated bottom, a mixture of Paris green and cornmeal. Where tobacco is sprayed with arsenites in the control of the "hornworm," this treatment will probably keep the bollworm in subjection.

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The synonymic *Heliothis rubrescens* listed, remarking that perhaps it is but a dark red variety of *Heliothis obsoleta*. Suggestive remarks on the varieties of the latter.

1883. Grote, A. R.—Remarks upon the North American Heliothinæ and their recent Literature. Trans. Amer. Ent. Soc., X, pp. 264–265.
On the genus Heliothis; a criticism of Smith (1882–1883).

1883. Johnson, L.—Report on the Cotton Worm, Bollworm, and other Insects. Bul. 1 (old series), Div. Ent., U. S. Dept. Agric., pp. 53–58.
Remarks on its abundance in Mississippi in 1882.

1883. Riley, C. V.—The Cotton Bollworm, or Corn Earworm. Insects in relation to Agriculture. Stoddart's Encyc. Americana, 1883, I, p. 141.
Brief general account.

1884. Mendenhall, R. J.—Entomological Notes of the Season of 1883. Trans. Minnesota State Hort. Soc., 1884, pp. 142–143.
Mentions characters, food habits, injuries, and remedies.

1884–1887. Moore, F.—The Lepidoptera of Ceylon, III, p. 57, figs. 1, 1a, of pl. 150.
Brief description of adult and larva; food of larva given as rosebuds; figures colored but rather poor.

1884. Rathvon, S. S.—The Corn worm (*Heliothis armigera*). Agric. Pennsylvania, Rept. State Bd. Agric. f. 1883, pp. 238–244, fig.
Good account of habits, life history, etc., on corn, including general descriptions of stages, with poor figures of the larvæ on corn, of the adult, pupa, and cocoon. Contains many errors.

1885. Riley, C. V.—The Bollworm. 4th Rept. U. S. Ent. Commission, pp. 355–385.
An excellent account, including the principal known facts up to that time.

1885. Webster, F. M.—Insects Affecting the Corn Crop. Rept. Indiana State Bd. Agric., XXVII, pp. 200–201, pls. V, fig. 4; VI, fig. 1.
Brief account, with synonymy.

1887. Meyrick, Edw.—Monograph of New Zealand Noctuina. Trans. N. Zeal. Inst. XIX (n. series II), 1886, pp. 34–35.
Distribution, description of adult, and larval food plants.

1888. Kent, G. H.—Some notes from Mississippi. Insect Life, I, p. 17.
But little injury to corn and cotton in 1887.

1888. KENT, G. H.—Injurious Insects in Mississippi for 1888. Insect Life, I, p. 217.
Mentioned as abundant on late corn; also injured cotton.

1889. BONHAM, L. N.—Blackbirds *vs.* Bollworms. Insect Life, II, p. 47.
Blackbirds observed feeding on bollworms in ears of corn.

1889. BRUNER, L.—Report of the Entomologist. Ann. Rept. Nebraska State Bd. Agric. f. 1888, pp. 95–97.
Vide Bruner (1891).

1889. COQUILLETT, D. W.—The Corn Worm or Bollworm in California. Insect Life, I, pp. 331–332.
Mentions pupation in the ears of corn. Food plants of larva; new parasite bred and described as *Tachina armigera.*

1889. COTES, E. C.—Indian Museum Notes, No. 1, I, pp. 50–51.
Reference made to bollworms injuring poppy.

1889. COTES, E. C.—Entomology Notes; *Heliothis armiger.* Indian Mus. Notes, I, pp. 97–103.
An account of the insect as injurious to opium.

1889. DRUCE, H.—*Heliothis armiger.* Biol. Centrali-Amer., Insects, Lep. Het., I, pp. 299–300.
Synonymy and habits; variability.

1889. EDITORS.—Notes and News. Science, N. Y., XIV, No. 346, Sept. 20, 1889, pp. 196–197.
Bollworm active in all sections of the cotton belt; gives total loss to cotton from combined insect attack.

1889. KENT, G. H.—Notes of the Season from Mississippi. Insect Life, II, p. 283.
Includes brief note on occurrence of the bollworm on cotton and corn in 1889.

1889. RILEY, C. V., and L. O. HOWARD.—A Bollworm Letter. Insect Life, I, p. 320.
London purple and Paris green advised.

1889. RILEY, C. V., and L. O. HOWARD.—The Bollworm in Texas. Insect Life, II, pp. 20–21.
A correspondent attributes a yearly loss to cotton of from $300,000 to $400,000 from the bollworm.

1889. TOWNSEND, C. H. T.—Some Michigan Notes Recorded. Insect Life, II, p. 42.
Bollworms observed but once during a period of 12 years. In 1881 were frequently observed in green corn.

1889. WASHBURN, F. L.—Corn Worm. Bul. No. 3, Oregon Agric. Exp. Sta., pp. 7–9, figs. 19, 20, 22.
An account of the insect in Oregon, with suggestions for remedies. Had been known in the State for about 8 or 10 years previously. Three generations are reported. Figures stages, and injured corn.

1889. WOODWORTH, C. W.—Report of the Entomologist. Ann. Rept. Arkansas Agric. Exp. Sta. f. 1889, p. 146.
Economic notes.

1890. BECKWITH, M. H.—Report of the Entomologist. 2nd Ann. Rept. Delaware Agr. Exp. Sta., 1889, pp. 126–128, fig. 24, p. 132.
A reprint of Bul. 4, Del. Agric. Exp. Sta.

1890. KENT, G. H.—Notes from Mississippi. Insect Life, III, p. 338.
Bollworm reported as having reduced cotton crop fully two-fifths in 1890.

1890. LINTNER, J. A.—The Cut Worm. Cult. and Country Gentleman, July 24, 1890, LV, p. 590.
Answer to correspondent; advises sugaring, and cites an instance in which successful.

1890. MARTIN, G. A.—The Corn Worm or Bollworm. Amer. Agriculturalist, 1890, p. 418.
Record of injury in New Jersey, including notes on habits and treatment.
1890. MURTFELDT, M. E.—Entomological Notes for the Season of 1890. Bul. No. 23, old series, Div. Ent., U. S. Dept. Agric., p. 46.
Noted as especially injurious in Missouri in 1890.
1890. NEAL, J. C.—Entomological Notes. Bul. No. 9, Florida Agric. Exp. Sta., p. 8.
Deep winter plowing recommended.
1890. OLLIFF, A. S.—Insect Pests—The Maize Moth (*Heliothis armiger*). Agric. Gaz. N. South Wales, I, pp. 125–127, Pl. II, figs. 1–8.
Tolerably good general account, with poor figures.
1890. RILEY, C. V., and L. O. HOWARD.—The Bollworm. Insect Life, II, p. 317.
Paris green recommended for poisoning the larvæ.
1890. RILEY, C. V., and L. O. HOWARD.—London purple and Paris green for the Bollworm. Insect Life, III, pp. 123–124.
Recommended for control of the bollworm, with directions for their use.
1890. SMITH, J. B.—The Corn Worm. Report of the Entomologist. Ann. Rept. N. Jersey Agric. Exp. Sta. f. 1890, pp. 516–518.
Unusual injury to corn mentioned; two broods recorded for New Jersey.
1891. BRUNER, L.—Bul. No. 23, old series, Div. Ent., U. S. Dept. Agric., p. 9.
Less destructive to corn than usual along the Mississippi River in 1890.
1891. CLARK, J. W.—Damage to Geraniums by Heliothis; cannibalistic habit of the larva. Insect Life, III, p. 399.
Notes damage to geraniums in greenhouse at Columbia, Missouri.
1891. COTES, E. C.—Agricultural Entomology. Jour. Bombay Nat. Hist. Soc., VI, p. 240.
Lecture delivered before the Agricultural-Horticultural Society, Calcutta, March 19, 1891. The bollworm on pods of opium poppy in India; larva omnivorous. Very interesting notes on local habits in regard to food and mode of pupation.
1891. COTES, E. C.—Indian Museum Notes, II, p. 24.
Remarks on habits and food plants.
1891. HUNTER, W. N.—Injurious Insects of Nebraska. Insect Life, IV, p. 132.
Serious injury to corn is reported in Nebraska in 1891.
1891. MALLY, F. W.—The Bollworm of Cotton. Bul. No. 24, old series, Div. Ent., U. S. Dept. Agric., p. 50.
A report of progress in a supplementary investigation of the bollworm.
1891. MALLY, F. W.—Report of Progress in the Investigation of the Cotton Bollworm. Bul. No. 26, old series, Div. Ent., U. S. Dept. Agric., pp. 45–56.
Discusses distribution, food plants, characters and transformations, number of broods, hibernation, natural enemies and remedies.
1891. RILEY, C. V.—Report of the Entomologist. Ann. Rept. U. S. Dept. Agric. f. 1890, pp. 240–241.
Remarks on the supplementary investigation of the bollworm undertaken in 1890.
1891. RILEY, C. V.—The Outlook for Applied Entomology. Insect Life, III, p. 181.
Arsenical poisons advised for the bollworm, with directions for use.
1891. SMITH, W. W.—Abundance of Lepidoptera in New Zealand. Entomologist, London, XXIV, p. 213.
Distribution and occurrence. Discusses theory of distribution.
1891. TOWNSEND, C. H. T.—Notes of Interest. Insect Life, IV, p. 26.
Includes reference to injury to corn by bollworms in New Mexico, during July, 1891.

1891. Tozzeti, Ad. Targioni.—Animali ed insetti del tabacco in Erba e del tabacco secco. Firenze-Roma, pp. 275–278, Tav. III, fig. 1, text fig. 96.
Good account with synonomy, names, and description of the adult. Figures larval injury to tobacco, and gives habits, food plants, etc. Remedies briefly noted.

1891. Webster, F. M.—Early Published References to Some of Our Injurious Insects, II. Insect Life, IV, p. 326.
Records occurrence of what is probably *Heliothis obsoleta* in 1820 on cotton; and in 1842 on corn in Illinois.

1892. Arkle, J.—A Tomato Caterpillar (*Heliothis armigera*). Entomologist, London, XV, pp. 237–238.
Life-history notes on larvæ in tomatoes imported from Valencia; range and food plants.

1892. Bruner, L.—Report of the Entomologist. Ann. Rept. Nebraska State Bd. Agric. f. 1891, pp. 252–255.
General considerations. Common injurious insect to corn in Nebraska.

1892. Garman, H.—Rept. Kentucky Agric. Exp. Sta. f. 1889, p. 9.
Brief account of injury in Kentucky.

1892. Harvey, F. L.—Report of the Entomologist. Ann. Rept. Maine Agric. Exp. Sta. f. 1892, pp. 119–123, fig. 4.
The bollworm or cornworm is figured and described with remedial measures. Apparently the first record of injury in Maine; one brood reported.

1892. Mullen, S. B.—Corn as a trap crop for the Bollworm. Insect Life, V, p. 48.
Tomatoes reported protected by use of corn as a trap crop.

1892. Neal, J. C.—Insects. Bul. No. 3, Oklahoma Agric. Exp. Sta., pp. 9–11, fig. 5.
General account with old figure.

1892. Smith, J. B.—Report of the Entomologist. Rept. N. Jersey Agric. Exp. Sta. f. 1892, pp. 441–446.
General considerations in New Jersey; number of broods.

1892. Smith, J. B.—Notes of the Year in New Jersey. Insect Life, V, p. 93.
Includes reference to serious injury to tomato in New Jersey by the bollworm; locally known as the "heart-worm."

1892. Townsend, C. H. T.—The Possible and Actual Influence of Irrigation on Insect Injury in New Mexico. Insect Life, V, p. 78.
Expresses the opinion that irrigation will destroy pupæ of bollworm in the ground.

1892. Tutt, J. W.—The British Noctuæ and Their Varieties, III, pp. 121, 128.
Its remarkable distribution mentioned; varies excessively. Varieties *fusca* Ckll., *ochracea* Ckll., and *umbrosus* Grote listed; subvariety *eumaculata*.

1893. Alwood, W. B.—Insects and Insecticides. Bul. No. 24, Virginia Agric. Exp. Sta., p. 13.
Brief account, with remedial suggestions. Protecting corn by application of strong tobacco decoction, etc., to the silks.

1893. Bairstow, S. D.—The Bollworm or Corn Worm of the southern United States—The Peach Underwing of the Cape. Agric. Jour., Dept. Agric. Cape Colony, S. Africa, 1893, VI, p. 81.
Reported serious enemy to peaches in 1892, in Cape Colony.

1893. Cotes, E. C.—Conspectus of the insects which affect crops in India. *Heliothis armiger*. Indian Mus. Notes, II, No. 6, p. 160.
List of Indian food plants.

1893. Editors.—The Maize Moth (*Heliothis armigera*, Hüb.). Agric. Gaz. N. South Wales, IV, pp. 213–214.
Notice of injury, with discussion.

1893. Mally, F. W.—The Bollworm of Cotton. Bul. No. 29, old series, Div. Ent., U. S. Dept. Agric., pp. 73.
Final report on investigations; treats of natural enemies, and habits; remedies and bacteriological experiments with insect diseases.

1893. Morgan, H. A. and F. H. Burnette.—Bul. No. 22, Louisiana Agric. Exp. Sta., p. 698.
Record of experiments in growing sweet corn to avoid bollworm injury.

1893. Rolfs, P. H.—Enemies of the Tomato. Bul. No. 21, Florida Agric. Exp. Sta., pp. 19–23.
General account as an enemy to tomatoes.

1893. Smith, J. B.—Ent. News, 1893, p. 10.
Injury to early tomatoes in New Jersey. Remedies.

1893. Stedman, J. M.—Injurious and Beneficial Insects. Some Insect Pests of the Farm and Garden. Bul. No. 45, Alabama Agric. Exp. Sta., pp. 32–34, 35–36, figs.
Popular account, with figures after Riley.

1893. Webster, F. M.—Insect Foes of American Cereal Grains, with Measures for their Prevention or Destruction. 24th Ann. Rept. Ent. Soc. Ontario, pp. 91–92.
Number of broods in the North; suggests remedies.

1893. Weed, H. E.—Remedies for Insects Injurious to Cotton. Insect Life, VI, pp. 168–170.
Consideration of remedial measures for the bollworm.

1894. Ashmead, W. H.—Notes on Cotton Insects found in Mississippi. Insect Life, VII, p. 25.
Reference is made to an investigation of the bollworm in Mississippi.

1894. DuPré, J. F. C.—Bul. No. 16, S. Carolina Agric. Exp. Sta., p. 3.
Notes destruction of tomatoes, and suggests hand picking as a remedy.

1894. Hampson, G. F.—*Heliothis armigera*. Fauna British India, II, pp. 174–175, fig. 114.
Good account with synonomy and figure; brief description of the larva, mentioning rose buds as food.

1894. Osborn, Herbert.—Corn Insects. Bul. No. 24, Iowa Agric. Exp. Sta., pp. 1003–1004, figs. 10, 11.
Brief descriptive notes, life-history, and remedies included. Two broods for Iowa.

1894. Riley, C. V.—Report of the Entomologist. Ann. Rept. U. S. Dept. Agric. 1893, pp. 199, 208.
References to special bollworm investigations.

1894. Smith, J. B.—Notes of the Year in New Jersey. Insect Life, VII, p. 185.
Reports serious injury to tomatoes in southern New Jersey.

1894. Webster, F. M.—Bul. No. 51, Ohio Agric. Exp. Sta., p. 138.
Brief notes; number of broods.

1895. Lounsbury, C. P.—Some Injurious Insects. Bul. No. 28, Mass. Agric. Exp. Sta., pp. 16–17, fig. 8, a–f.
Brief account, with old copied figures of the stages.

1895. Lugger, O.—The Sweet-corn Moth or Tassel-worm. Bul. No. 43, Minnesota Agric. Exp. Sta., pp. 196–200, pl. 11, fig. 54.
General account of life-history, enemies, and remedies, with figures of the stages from photographs.

1895. Musson, C. T.—Entomological Notes. Agric. Gaz. N. South Wales, VI, p. 263.
The army worm; brief account of occurrence and remedies.

1895. Weed, H. E.—Insects Injurious to Corn. Bul. No. 36, Mississippi Agric. Exp. Sta., pp. 150–152.
Popular account of life-history with remedies.

1896. Lowe, V. H., and F. A. Sirrine.—Report of the Entomologists. Rept. New York State Agric. Exp. Sta. 1895, pp. 559–565.
Discussion with especial reference to injuries to sweet corn in southeastern New York in 1895. Fall plowing recommended for the north.

1896. Arkle, J.—*Heliothis armigera* imported with tomatoes. Entomologist, London, XXIX, p. 334.
Records importation; habits of larvæ in confinement.

1896. Ashmead, W. H.—Proc. Ent. Soc. Washington, IV, p. 32.
Brief remarks on the cause of variation in the adult.

1896. Cockerell, T. D. A.—Bul. No. 19, N. Mexico Agric. Exp. Sta., p. 102.
Brief note of injury to corn in New Mexico; food-plants of larva. Adult varieties mentioned.

1896. Hopkins, A. D. and W. E. Rumsey.—The Corn-ear Worm. Bul. No. 44, W. Virginia Agric. Exp. Sta., p. 282.
Mentions number of broods; brief account.

1896. Howard, L. O.—Insects Affecting the Cotton Plant. Bul. No. 33, Office of Exp. Stations, U. S. Dept. Agric., p. 328.
Full account, with directions for control.

1896. Price, R. H.—Saving Corn from the Bollworm. Amer. Gardener XVII, No. 83, p. 468.
Brief note; clipping ends of young ears recommended.

1896. Quaintance, A. L.—Insect Enemies of Truck and Garden Crops. Bul. No. 34, Florida Exp. Sta., pp. 264, 309–314, 323, 326.
Brief biological notes, and suggestions for control on tomatoes.

1896. Quaintance, A. L.—Brief Notes on the More Injurious Insects of the Year. Rept. Florida Agric. Exp. Sta., 1896, p. 57.
Larvæ noted as feeding on the vines and leaves of tomatoes.

1896. Smith, J. B.—The bollworm; corn worm. Economic Entomology, Philadelphia, pp. 303–305, figs. 342, 343.
Popular account, with remedies.

1897. Froggatt, W. W.—Report upon Insect Pests found in the Northern District, May, 1897. Agric. Gaz. N. South Wales, VIII, p. 717.
The most destructive pest to maize; urges protection of insectivorous birds; brief account.

1897. Garman, H.—Notes on the Several Tobacco Insects, and on several imperfectly known Diseases of Tobacco. Bul. No. 66, Kentucky Agric. Exp. Sta., p. 35.
Note on injury to tobacco.

1897. Hillman, F. H.—Some Common Injurious Insects of Western Nevada. Bul. No. 36, Nevada Agric. Exp. Sta., p. 19.
Brief notes; destructive to sweet corn and occasionally to tomatoes; two broods.

1897. Howard, L. O.—Some Miscellaneous Results of the Division of Entomology. Bul. No. 7, n. series, Div. Ent., U. S. Dept. Agric., p. 84.
Notes from correspondents. Injuring strawberries in fall.

1897. Howard, L. O.—Insects Affecting the Cotton Plant. Farmers' Bul. No. 47, U. S. Dept. Agric., p. 10.
Revised account. *Vide* Howard (1896).

1897. MORGAN, H. A.—Bul. No. 48, Louisiana Agric. Exp. Sta., p. 155.
Moths observed in large numbers in grass, surrounding electric lights.

1897. WEBSTER, F. M. and C. W. MALLY.—Insects of the Year in Ohio. Bul. No. 9, n. series, Div. Ent. U. S. Dept. Agric., p. 41.
Records injury to ripening peaches, to ripening tomatoes, and to geraniums in the fall, in greenhouses.

1898. CHITTENDEN, F. H.—Insects Injurious to Beans and Peas. Yearbk. U. S. Dept. Agric., 1898, p. 255.
Brief account of injuries to those crops.

1898. CURTIS, W. P.—*Heliothis armigera.* Entomologist, London, XXXI, p. 45.
Records importation from Portugal with tomatoes.

1898. FERNALD, H. T.—Supplementary Report of the Zoologist. Rept. Pennsylvania Dept. Agric., 1898, pt. I, pp. 426–427.
Brief discussion; reported quite abundant; from two to three broods.

1898. HOWARD, L. O.—The Principal Insects Affecting the Tobacco Plant. Yearbk. U. S. Dept. Agric., 1898, p. 132.
Brief account as injurious to tobacco.

1898. HUDSON, G. V.—New Zealand Butterflies and Moths (Macrolepidoptera), London, pp. 32–33, figs. 40, 41 of pl. V.
Occurrence, variation, food plants, and distribution. Poor colored figures of male and female.

1898. QUAINTANCE, A. L.—Preliminary Report upon the Insect Enemies of Tobacco in Florida. Bul. No. 48, Florida Agric. Exp. Sta., p. 185.
Recorded as injuring tobacco buds; remedy suggested.

1898. ROLFS, P. H.—Diseases of the Tomato. Bul. No. 47, Florida Agric. Exp. Sta., pp. 141–143.
Hand picking of the infested fruit recommended.

1898. SOUTH, RICHARD.—*Heliothis armigera.* Entomologist, London, XXXI, pp. 17–19.
History of in England to date; mentions injury in the United States, with food plants.

1898. WEBSTER, F. M. and C. W. MALLY.—The Army Worm and other insects. Bul. No. 96, Ohio Agric. Exp. Sta., pp. 15–18, pl. III, fig. 1; pl. IV, fig. 1.
Number of generations in southern and northern Ohio. Tachinid parasites of larva.

1899. COCKERELL, T. D. A.—Some Insect Pests of the Salt River Valley and Remedies for them. Bul. No. 32, Arizona Agric. Exp. Sta., p. 32.
Brief notes; injury to corn; refers to the advantage of planting sweet corn late, in New Mexico, to avoid injury.

1899. DEARNESS, J.—The Cotton Bollworm in Canadian Corn. 29th Ann. Rept. Ent. Soc. Ontario, 1898, pp. 64–65.
Prevalence of the bollworm in corn in Ontario in 1898.

1899. FLETCHER, JAMES.—The Corn Worm. 29th Ann. Rept. Ent. Soc. Ontario, 1898, p. 82.
Remarks on occurrence and ravages in Ontario.

1899. FLETCHER, JAMES.—Recent Addition to the List of Injurious Insects of Canada. Trans. Royal Soc. Canada, series 2, V, section iv, p. 215.
H. obsoleta by no means frequent, but occasionally very injurious to sweet corn. *Vide* preceding.

1899. MEYRICK, EDW.—Macrolepidoptera. Fauna Hawaiiensis, I, pt. ii, pp. 137, 152.
Localities in Hawaii; mentions adult variability and the synonymic variety *conferta* Walker; presence of a native race.

1899. Quaintance, A. L.—Some Insects and Fungi Destructive to Truck and Garden Crops. Proc. 23d. Ann. Meeting Georgia State Hort. Soc., pp. 51–52.
Serious injury to sweet corn and tomatoes noted.

1899. Smith, J. B.—*Heliothis armiger.* Insects of New Jersey. Suppl. 27th Ann. Rept. New Jersey State Bd. Agric., 1899, p. 426, fig.
Brief remarks.

1900. Barlow, E.—Notes on the Insect Pests from the Entomological Section, Indian Museum. Indian Mus. Notes, V, No. 1, pp. 22–23.
Brief economic notes.

1900. Editorial.—Les Plantes de France. Leurs Chenilles et leurs Papillons. Le Naturaliste, XXII (series 2, XIV), pp. 44, 55, 151.
Larva recorded feeding on the following: Cucurbita, Cannabis, and *Ajonc europæus*, with brief notes on distribution.

1900. Froggatt, W. W.—Cutworms. Agric. Gaz. N. South Wales, XI, p. 530.
Answer to correspondent. Larvæ on tomatoes; recommends poisoning with Paris green.

1900. Gossard, H. A.—Ann. Rept. Florida Agric. Exp. Sta., 1899, p. 75.
Mentions severe injury to tomatoes in Florida.

1900. Guercio, G. del.—Biological and Economical Notes on the Bollworm. Nuove Relaz R. Staz. Agric., series I, 1900, No. 3, pp. 143–159.
Description of stages and account of habits, life-history, and natural enemies; list of remedies. Recommends tobacco decoction.

1900. Lea, A. M.—The More Common Insect Pests of the Farm and Garden. Jour. Dept. Agric. West Australia, II, pt. 6, pp. 404–407.
Brief notes.

1900. Leech, J. H.—Lepidoptera Heterocera from Northern China, Japan, and Corea, III. Trans. Ent. Soc. London, 1900, p. 22.
Heliothis obsoleta and *H. succinea* listed separately with synonymy and distribution of each. Under *succinea*, *Heliothis armiger* is listed as a synonym.

1900. Quaintance, A. L.—Insect Notes. Rept. Georgia Agric. Exp. Sta., 1900, p. 362.
Includes brief notice of ravages of the bollworm.

1900. Sanderson, E. D.—The Corn Ear Worm. Ann. Rept. Delaware Agric. Exp. Sta., 1900, p. 209.
Record of serious injury to sweet corn in Maryland and Delaware. Three broods recorded.

1900. Smith, J. B.—The Corn Worm. Rept. of the Entomologist. Rept. N. Jersey Agric. Exp. Sta. f. 1900, p. 490.
Extent of injury to corn in New Jersey. Fall plowing recommended.

1900. Smith, W. W.—*Heliothis armiger.* Entomologist, London, XXXIII, pp. 201–202.
Mentions erratic occurrence in New Zealand; moths captured by a plant.

1900. Southwick, J. M.—Report of the Entomologist. Rept. Rhode Island State Bd. Agric., 1900, pp. 34–35.
Record of injuries in Rhode Island; probably but a single brood.

1901. Froggatt, W. W.—Caterpillar Plague, with account of the Potato Pests at Windsor. Agric. Gaz. N. South Wales, XII, p. 241.
Recorded as injuring potatoes; one to two inches beneath the soil during the day and feeding at night like cutworms. There called the common cutworm.

1901. Lochhead, Wm.—Insects of the Season of 1900. 31st Ann. Rept. Ent. Soc. Ontario, 1900, p. 75, fig.
Remarks on occurrence in Ontario; one brood probable; poor figure of injury to corn.

1901. Murtfeldt, M. E.—Drought, Heat, and Insect Life. Bul. No. 31, n. series, Div. Ent. U. S. Dept. Agric., p. 97.
The effects of drought on the bollworm noted.

1902. Sanderson, E. D.—Insects Injurious to Staple Crops, New York, pp. 27, 201-205, figs. 115, 124, 125.
General account of the bollworm.

1903. Hampson, G. F.—Catalogue Lepidoptera Phalaenæ in the Collection of the British Museum, IV, pp. 45-46, fig. 18.
Includes in the genus Chloridea, with text-figures of moth and details; synonomy, and a long list of localities given.

1903. Hart, C. A.—Synopsis of Insect Collections for distribution to Illinois High Schools. Lepidoptera. Illinois State Lab. Nat. Hist., 1903, p. 38, fig. 51.
Mentions food, broods, and habits, and that adults were common at lights in the fall.

1903. Holland, W. J.—*Heliothis armiger* Hübner (The boll-worm). The Moth Book, N. Y., 1903, pp. 222-224, pl. xxvii, fig. 17, text-figs., 130, 131.
Brief popular account; rather good colored figure of a male; text-figures after Riley.

1903. Quaintance, A. L.—The Cotton Boll Worm. Proc. 2nd Ann. Session Texas Cotton Convention, Dallas, Tex., Nov., 1903, pp. 50-60, figs. 1-4.
Abstract of an illustrated lecture delivered before the Texas Cotton Convention at Dallas, Tex. General account, with illustrations of the injury to corn and cotton.

1903. Sherman, Franklin, Jr.—The Cotton Bollworm. Entomological circ. No. 2, N. Carolina Dept. Agric. Oct. 31, pp. 1-6.
Condensed account, with remedial measures.

1904. Forbes, S. A.—The more Important Insect Injuries to Indian Corn. Bul. No. 95, Illinois Agric. Exp. Sta., p. 397.
General account as an enemy of corn in Illinois.

1904. Quaintance, A. L.—Bollworm. Proc. Ent. Soc. Washington, VI, p. 66.
A few brief notes; records the number of eggs deposited by moths in confinement as 2,200.

1904. Quaintance, A. L.—The Cotton Bollworm: An account of the Insect, with results of Experiments in 1903. Farmers' Bul. No. 191, U. S. Dept. Agric., pp. 24.
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